PB-230 264

EFFLUENT QUALITY AND TREATMENT ECONOMICS FOR INDUSTRIAL WASTEWATERS

W. Wesley Eckenfelder, Jr.
Austin, Texas

October 1967

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

PB 230 264

EFFLUENT QUALITY AND TREATMENT ECONOMICS

FOR

INDUSTRIAL WASTEWATERS

Prepared For

The Federal Water Pollution Control Administration

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

W. Wesley Eckenfelder, Jr.

Consultant in Water Quality Management

Austin, Texas

October, 1967

132

W. WESLEY ECKENFELDER, JR.
CONSULTANT IN WATER QUALITY MANAGEMENT
1107 WEST 31ST STREET
AUSTIN, TEXAS 78705

October 11, 1967

Dr. Allen Hirsch
Assistant Commissioner
Project Plans and Development
Federal Water Pollution Control Administration
Room 1100
633 Indiana Avenue
Washington, D. C.

Dear Dr. Hirsch:

In accordance with our proposal of August 3, 1967, and Contract WA 68-96, we are pleased to submit our report "Effluent Quality and Treatment Economics for Industrial Wastewaters." The report includes four phases, namely (a) a statistical correlation of significant waste characteristics from 15 industrial categories. In cases where insufficient data was available for statistical significance, averages, maximums and minimums are provided, (b) a summary of effluent quality from treatment processes in use today in these industrial categories, (c) construction and operating costs for primary and secondary treatment of these industrial wastewaters and (d) a suggested procedure for optimizing and computerizing the data of (a), (b) and (c) above.

In the time available for compilation and preparation of this report, it was not possible to draw final conclusions on several phases of the report. It is felt however, that the data are available for future inclusion in the study.

The participation of Mr. Lial Tischler, Research Engineer and Mr. Chou-Shong Chow, Research Associate in the compilation and correlation of the data presented in this report and of Dr. Davis Ford in the formulation of the conclusions is acknowledged.

Respectfully submitted

W. Wesley Eckenfelder
Consultant

WWE:gl

ia

SUMMARY

This report gives statistical estimates of the significant pollution per product unit before treatment or by-product disposal for representative industrial wastewaters. Additional data are provided for waste characteristics which could not be statistically evaluated due to insufficient information. The effects on the quantities and qualities of pollutants due to in-plant variations are also discussed. Methods for projecting these statistical analyses to future operations are suggested. These data were compiled from published literature, consulting reports and private sources.

An extensive summary of industrial waste treatment is given. Types of treatment used and the effluent qualities obtained by various industries are listed. The efficiencies of primary and secondary treatment in these industries are evaluated and discussed.

Cost data, both capital and operating, for existing industrial waste treatment facilities are summarized. The relationships of capital costs to wastewater flows for various waste treatment processes were developed. Operation costs for unit processes are related to waste flow and quantity of pollutant treated. Meaningful cost estimates for waste treatment process design can be made from these relationships.

A complete method for the optimization of waste treatment design for any type of industry is provided. The complete solution, as illustrated by a flow diagram and an example problem is presented. The waste characteristic and cost relationships presented in this report are used to develop the optimized solution. Effluent quality can be predicted from data obtained from existing treatment installations and extrapolations from laboratory and pilot plant studies. Future work will involve developing cost relationships for each of the unit processes used in primary, secondary and tertiary treatment to further verify the optimizing procedure.

TABLE OF CONTENTS

	Page
Summary	i
Table of Contents	ii
List of Tables	iii
List of Figures	iv
Symbols and Abbreviations	v
Introduction	1
Industrial Waste Characteristics	2
Statistical Analysis of Average Wastewater Discharges and Characteristics from Representative Industries	
Miscellaneous Industrial Wastewater Characteristics	
In-Plant Wastewater Variations	
Types of Industrial Waste Treatment - Effluent Quality from Present Treatment Facilities	10
Capital and Operating Costs of Representative Industrial Waste Treatment Plants	20
Projected Optimized Solution for Estimating Industrial Waste Treatment Cost and Effluent Quality	28
Appendix	
Appendix A Tables of Characteristics	A-1
Appendix B Statistical Plots	B-1
Appendix C Tables of Industrial Waste Treatment, Effluent Qualities and Costs	C-1

LIST OF TABLES

		Page
Table i	Statistical Evaluation of the Characteristics of Representative Industrial Wastewaters	4
Table 2	Average BOD:COD:N:P Ratios for Various Industrial Wastes	6
Table 3	Industrial Waste Treatment Process Efficiencies	11
Table 4	Industrial Waste Treatment Plants - Effluent Quality	12
Table 5	Waste Treatment Plant Operating Costs - Existing Industrial and Municipal Facilities	27
Table 6	Effect of Wastewater Variation on Process Design of Biological Treatment - Activated Sludge	32
Table 7	Suggested Bases for Costing Unit Processes	35
Table 8	Coefficients Required for Biological Treatment Design	37
Table 9	Summary of Design Relationships	39
Table 10	Summary Process Design Criteria and Performance	40
Table 11	Design Parameters - Example Problem	47
Table A-1	Industrial Waste Characteristics	A-1
Table C-1	Treatment Performance and Costs of Construction and Operation - All Industries	C-1
Table C-2	Daily Operating Costs - Industrial Waste Treatment	C-10

LIST OF FIGURES

		Page
Figure 1	In-Plant Flow Variation - Refinery	7
Figure 2	In-Plant flow and Suspended Solids Variation - Cannery	8
Figure 3	Capital Cost - Activated Sludge Treatment - All Industries	22
Figure 4	Capital Cost - Aerated Lagoon Treatment - All Industries	23
Figure 5	Cost vs Flow - Extended Aeration - Chemical Industry	24
Figure 6	Cost vs Flow - Primary Treatment - Pulp and Paper Industry	25
Figure 7	Cost vs Flow - Aerated Lagoon Treatment - Pulp and Paper Industry	26
Figure 8	Industrial Waste Treatment Design and Effluent Quality	29
Figure 9	Typical Effluent Quality - Cost Analysis Relationship for a Particular Industrial Category and Wastewater Flow	30
Figure 10	Optimized Solution for Industrial Waste Treatment - Flow Diagram	33
Figure B-1	Statistical Plots - Wastewater Characteristics	B-1

Symbols and Abbreviations

a	volatile suspended solids synthesized per unit of BOD or COD removed
a'	energy fraction-oxygen required per unit of BOD removed
ABS	alkyl benzene sulfonates (detergent)
API	oil separator, Amer. Petrol. Institute
b	endogenous respiration factor
b'	endogenous respiration factor (oxygen basis)
BOD_5	biochemical oxygen demand, 5 day incubation at 20°C
Cl	Chlorides, mg/l
COD	chemical oxygen demand
D.S.	dissolved solids, mg/l
G	Sludge Age
gpd	gallons per day
F	organic loading, lb BOD/lb MLVSS·day
Mgd	millions of gallons per day
mg/l	milligrams per liter, ppm
MLSS	mixed liquor suspended solids
MLVSS	mixed liquor volatile suspended solids
n	recycle ratio, activated sludge process
N	Nitrogen
NH_3	Ammonia Nitrogen, mg/l
ppm	parts per million, mg/l
P	Phosphorus
S	Sulfides, mg/l
S_a	applied BOD or COD, biological treatment
S_e	effluent BOD or COD, biological treatment
SO_4	Sulfates, mg/l
SS	suspended solids, mg/l
t	aeration detention time
T	temperature
TF	trickling filter
TOC	total organic carbon, mg/l
TS	total solids, mg/l
VS	volatile solids, mg/l
VSS	volatile suspended solids, mg/l
VF	vacuum filtration

INTRODUCTION

The increasing emphasis on industrial water pollution control requires better methods for the prediction of quantities and qualities of industrial wastewaters, the type and extent of treatment needed and the capital and operating costs for these treatment facilities.

To adequately estimate quantities and qualities of industrial wastes, it is necessary to statistically analyze data obtained from existing industrial plants. Future projections of wastewater characteristics must include provisions for correcting for increased industrial water reuse and better in-plant control.

In-plant variations in waste characteristics are important in waste treatment design and operation. A method of estimating these variations will be needed if industrial waste treatment design is to be optimized.

Capital and operational costs of industrial waste treatment processes are a primary factor in process selection. Estimation of costs can be made on either a wastewater flow or pollutant quantity basis. More information is required before adequate cost projections can be made.

The procedure for waste treatment process design is well developed. Once the required data are obtained, design is a well-defined step by step process. A method for optimizing industrial waste treatment design is suggested in this report. When the designs for alternate treatment schemes are completed, the optimum design can be selected based on capital and operation cost estimates.

This report includes four principal sections as follows:

A. A statistical estimate of significant pollution per product unit before treatment or by-product disposal of wastes including (1) flow, (2) BOD, (3) suspended solids (and where available nitrogen), (4) phosphorus, (5) COD, and (6) dissolved solids.

B. Types of treatment now in use in these industries, the removal efficiency of these treatment systems, and the resulting effluent quantity. Effluent quality will be expressed in terms of BOD, COD, TOC, suspended solids, pH, and where available total dissolved solids, nitrogen, and phosphorus.

C. A summary of costs of construction and operation of industrial waste treatment facilities adjusted to an Engineering News Record Index of 970.

D. Projections of a method of procedures to computerize waste treatment design and effluent quality for these eleven industries and development of construction costs on a unit treatment process basis for varying degrees of effluent quality.

INDUSTRIAL WASTE CHARACTERISTICS

In order to determine the variation in wastewater flow and characteristics from representative process industries, a statistical evaluation was made of data available from published papers and reports, engineering studies and reports and private communications.

Table 1 shows a statistical evaluation of the wastewater characteristics per unit of production from 14 representative industries. Considering these characteristics in terms of production units for each industrial category facilitates prediction of the wastewater characteristics for a new plant or the addition of production capacity to an existing plant. These data consist primarily of flow, BOD and suspended solids, which were the only data sufficiently available in the literature and other sources to analyze statistically. In some cases, the data could not be normalized arithmetically or geometrically. Such data were averaged arithmetically with the maximum and minimum values used in Table 1 instead reporting one standard deviation from the mean.

The data and statistical plots used to develop the characteristics shown in Table 1 are presented in Table A-1 in the Appendix. Table 2 gives average additional characteristics for industries listed in Table 1. These data can be used to estimate the COD, nitrogen and phosphorus for various industrial wastewaters. The values shown in this Table are arithmetic means of data available in the literature and other sources. Additional characteristics of industrial wastewaters such as COD, TOC, and specific organic and inorganic constituents are presented in Table A-1 in the Appendix. These data were insufficient to be related to production units but offer additional supplementary information on the characteristics of the wastewater.

All of the data used in compiling Tables 1, 2 and A-1 are developed from sources as listed in the bibliography. These sources include various sanitary engineering and manufacturers journals and proceedings, consultants' reports and private communications.

The data used to statistically evaluate the characteristics of industrial wastes in Table 1 and Figure B-1 represents the differences between plants from within the same industrial category. One point represents the average waste characteristic value from a plant and in-plant variations are not considered.

In-plant variations in waste flow and characteristics, however, are important considerations in the design of waste treatment facilities. In any particular plant in an industrial category, there will be a statistical variation in flow and waste characteristics with time due to varying process operation, diversity of products manufactured, and operational control. Figure 1 shows the daily variation of wastewater flow discharged from a refinery. The in-plant variations of flow and suspended solids in a cannery are shown in Figure 2. These two examples demon-

strate the need for an industrial waste survey of a particular plant to establish the actual waste loadings and their variations.

The statistical variation of waste flow and characteristic between plants within an industrial category are important to determine present waste loadings and to predict future waste loadings as increased water reuse and product recovery is practiced. The statistical variation of waste flow and loading within a plant in any industrial category is needed to optimize process and plant design and resulting economics of treatment.

Industry	Unit	Flow - gal/unit			No. Data Points
		Mean	16%	84%	
Sugar Beet	Ton	3,000	1,250	4,750	15
Milk	1,000 lb Intake	195	115	320	31
Tannery	100 lb Hides	660	440	1,010	50
Poultry	1,000 Chickens Processed[b]	6,600	3,400	12,800	14
Oil Fields	bbl.[c]	140	68	215	6
Refinery	bbl.[c]	844	705*	1,270+	6
Synthetic Fiber	1,000 lb Fiber	14,360	5,000*	35,000+	11
Brewery	bbl.[d]	370	225	520	25
Textile	100 lb Goods[e]	450	110	1,900	81
Explosive	100,000 lb TNT	1,543,000	24,000*	8,300,000+	13
Meat Packing	1,000 lb Live Wt.	1,350	565	3,100	38
Potatoe Chips	Ton Potatoes[f] Processed	4,200	2,900	6,100	8
Pulping					
Kraft Pulp	Tons Pulp	37,000	21,000	54,000	18
Sulfite	Tons Pulp	53,933	20,000*	75,900+	6
Groundwood	Tons Pulp	4,220	2,300*	5,300+	5
Bleaching	Tons Pulp	28,000	3,000*	45,000+	3
Paper (All Types)	Tons Paper	28,500	13,500	44,000	26
Deinking	Tons Paper	51,450	-	-	2

Statistical Evaluation of the
Wastewate

BOD_5 - lb/unit			No. Data Points	S.S. - lb/unit			No. Data Points	Other - lb/unit			No. Data Points
Mean	16%	84%		Mean	16%	84%		Mean	16%	84%	
15.5	5.0	48	15	51.2	-	-	3				
1.70	0.74	2.75	35	-	-	-					
6.2	2.0	10.5	17	13.0	5.0	21.0	17				
26.4	16*	40.4[+]	14	16.1	11.6[+]	26.8[+]	11				
-	-	-	-	-	-	-					
-	-	-	-	-	-	-					
62	21	190	15	-	-	-					
1.90	0.84	4.2	27	1.03	0.43	2.5	22				
1.20	0.47	41.2[+]	88	0.49	0.19	1.3	35	15.5	Total Solids 5.5	43.0	64
,465	17*	8,360[+]	12	210	66	680	12				
12.5	5.8	19.4	56	12.0	0.58	18.7	56	1.5	NH_3 as N 0.97	2.3	16
47	31	71	8	72.5	39	106	7	1.32	Grease 0.5	3.5	25
90.5	38*	240[+]	8	76	35	167	17				
497	70*	825[+]	7	55.7	36*	101[+]	4				
21	-	-	2	12	-	-	2				
35	-	-	1	30	-	0	1				
39.1	5.0*	209[+]	22	60	17	210	21				
120.3	-	-	3	232	-	-	2				

Table 1
Characteristics of Representative Industrial
ers (per unit of production)

Industry	Unit	Flow - gal/unit			No. Data Points	BOD_5 - lb/unit			N
		Mean	16%	84%		Mean	16%	84%	
Paperboard	Tons Paperboard	9,625	3,400*	15,000+	4	52	29	76	
Cannery (Total)	Case #2 Cans	32	15	70	65	0.33	0.115	0.96	
Beans	Case #2 Cans	53	20	142	13	0.185	0.064	0.52	
Tomatoes	Case #2 Cans	12.5	2.2	70	9	0.23	0.086	0.63	
Corn	Case #2 Cans	48.6	25*	116+	9	0.72	0.22	2.35	

*Minimum Value
+Maximum Value
These are used to give a range of characteristics when the data could not be normalized either arithmetically or logarithmically.

a. #2 Cans, 24 cans per case.
b. 1 Bird = 1 Chicken = 2.5 lb, Duck = 4 lb.
c. 1 bbl = 42 gal.
d. 1 bbl = 31 gal.
e. These values are derived from a probability plot of all reported textile mills. These mills include different combinations of the following unit processes: boiler, kier, silk boiling, dyeing, pulling, desizing, printing, bleaching, scouring, mercerizing, and slashing. Therefore, the values represent an average of all textile mills processing wool, cotton, and silk, regardless of the particular unit processes used by a given mill.
f. 1000 lb Potatoes processed = 250 lb Potatoe Chips.

Table 1
Statistical Evaluation of the Characteristics of Repre
Wastewaters (per unit of productio

	BOD_5 - lb/unit			No. Data Points	S.S. - lb/unit			No. Data Points	Other - lb/unit			No. Data Points
	Mean	16%	84%		Mean	16%	84%		Mean	16%	84%	
	52	29	76	12	25.5	10.5	41	12				
	0.33	0.115	0.96	64	0.125	0.026	0.60	60				
	0.185	0.064	0.52	13	0.103	0.019	0.57	10				
	0.23	0.086	0.63	9	0.14	0.024	0.82	9				
	0.72	0.22	2.35	9	0.21	0.086	0.52	9				

Table 1

n of the Characteristics of Representative Industrial
astewaters (per unit of production)

TABLE 2

NUTRIENT CONTENT OF REPRESENTATIVE INDUSTRIAL WASTEWATERS

(All Values are Arithmetic Means)

Type	BOD	COD	N	P
Refinery	100	340	37	2
Cannery	100	-	3*	2
Potato	100	188	-	-
Brewery	100	-	4	1
Distillery	100	-	6	-
Tannery	100	-	15	-
Poultry	100	-	12	-
Paper & Pulp	100	400	2	0.6
Milk	100	135	4	2
Meat Packing	100	-	9	4
Explosives	100	-	1,000	-
Textile	100	-	5	1.5

* Average value for canning of beets, peas, beans, cauliflower, leaf vegetables, soft fruits, celery, spinach, and sprouts. This ratio can vary greatly depending on the vegetable or fruit processed. This value is only good for canneries using the above mentioned vegetables and fruits.

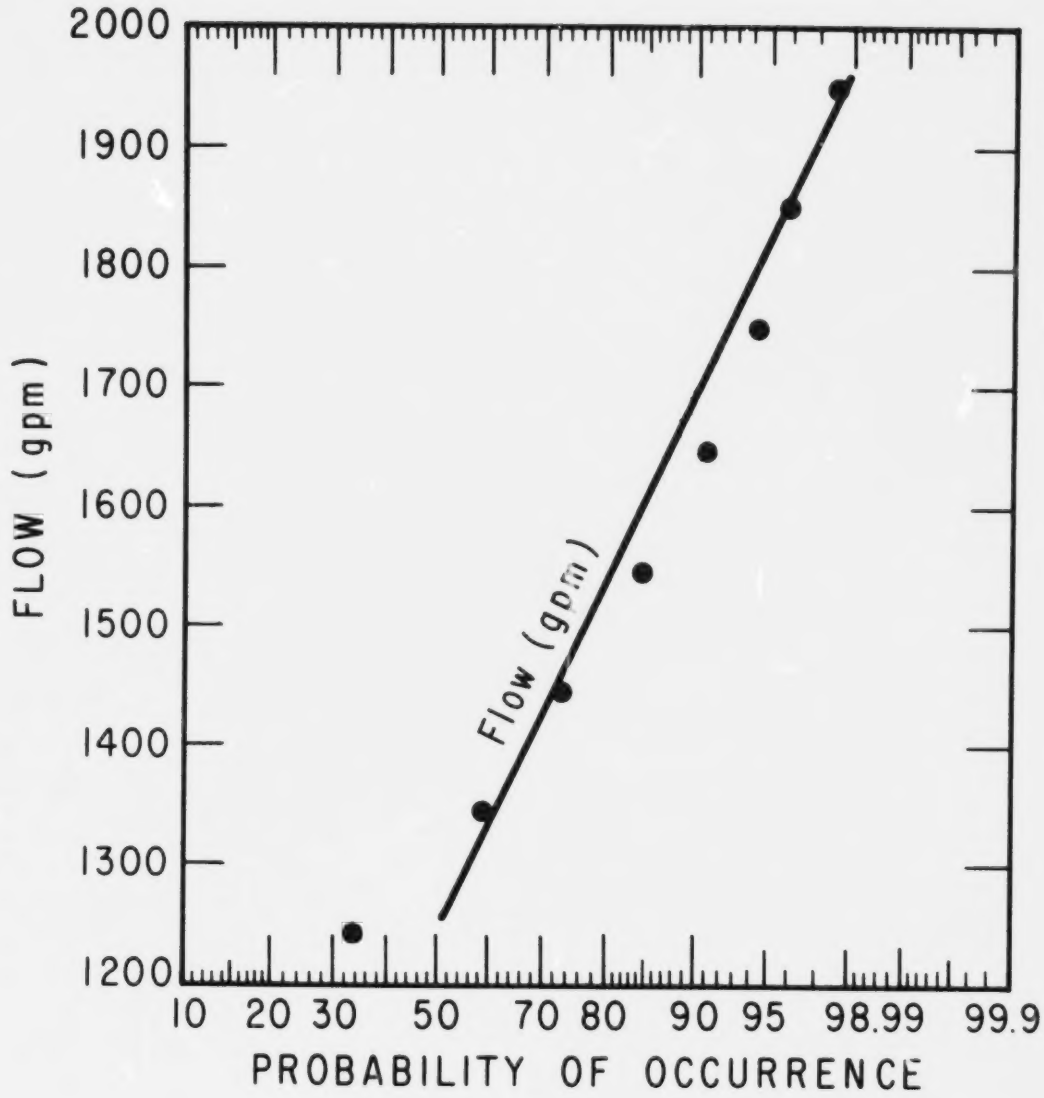


Figure 1

In-Plant Flow Variation

Refinery

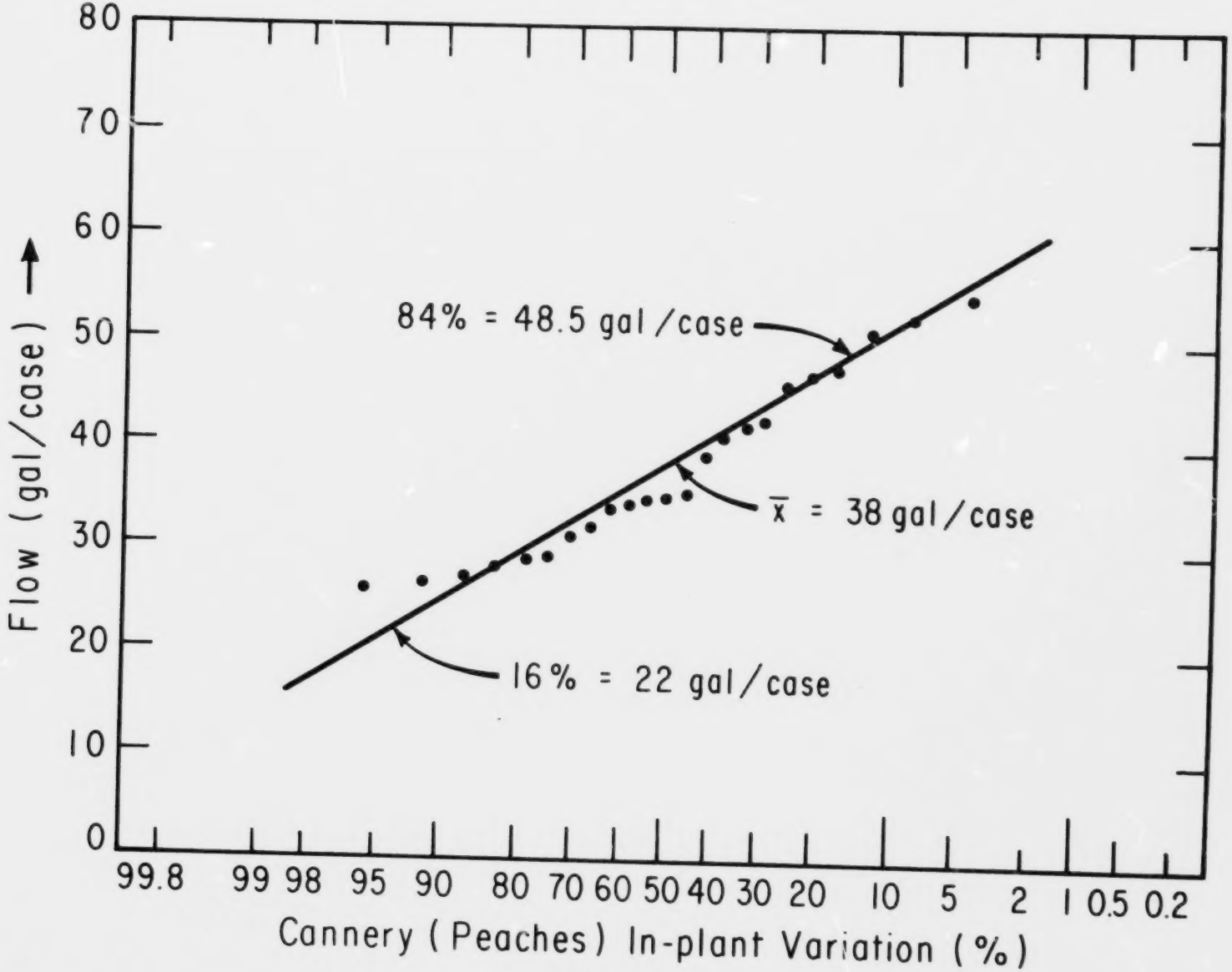

80
70
60
50
40
30
20
10
0
Flow (gal/case)
84% = 48.5 gal/case
$\bar{x}$ = 38 gal/case
16% = 22 gal/case
99.8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
Cannery (Peaches) In-plant Variation (%)

Figure 2

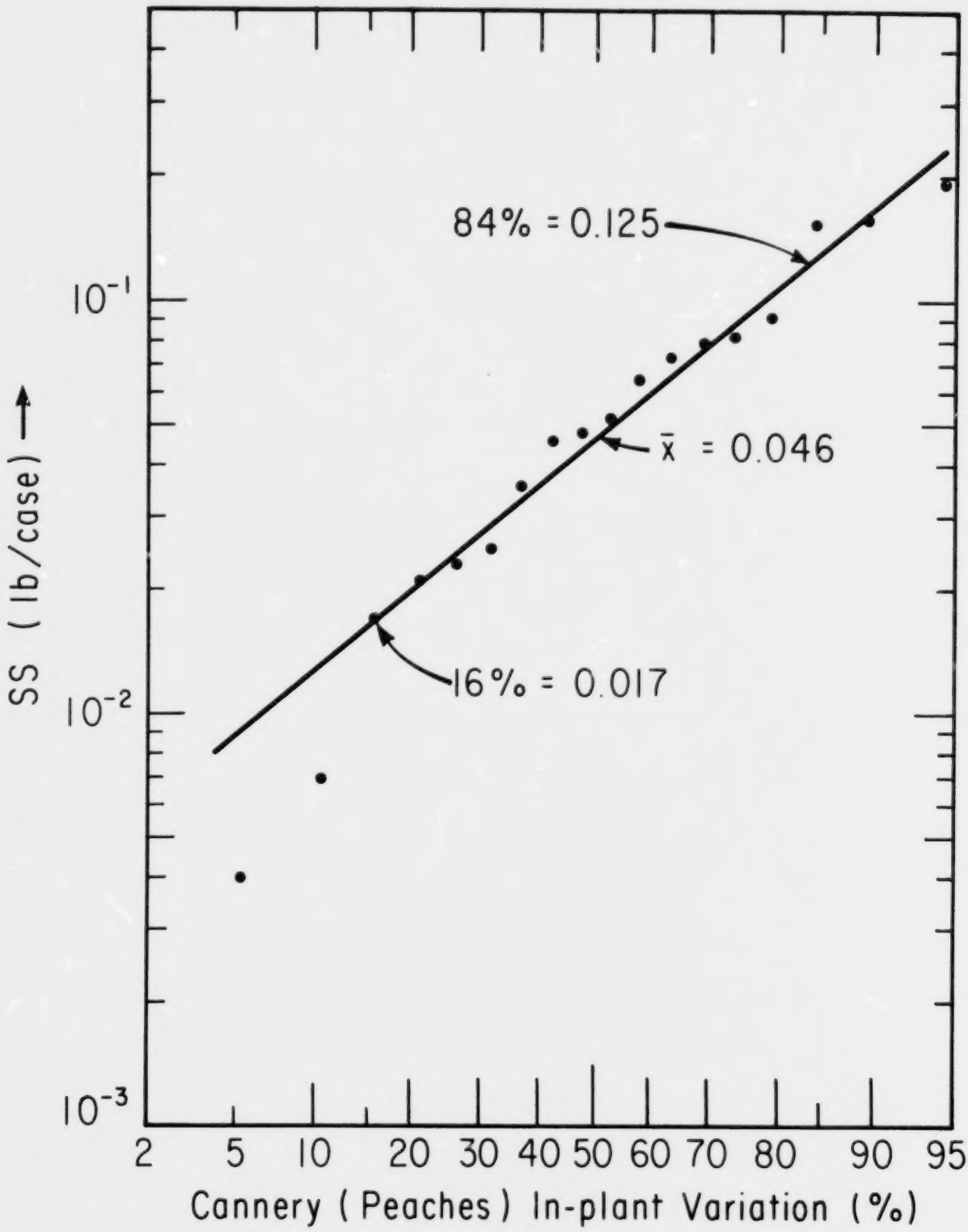


Figure 2
In-Plant Suspended Solids Variation - Cannery

TYPES OF INDUSTRIAL WASTE TREATMENT AND EFFLUENT QUALITY FROM PRESENT TREATMENT FACILITIES

Industrial waste treatment in this report for preliminary purposes of cost estimation and effluent classification has been broadly categorized as pre or primary treatment, secondary treatment and sludge handling and disposal.

Table 3 gives the ranges of efficiencies for the various processes used in the treatment of industrial wastes. The treatment processes are listed under the respective industries for which they are used and are divided into two categories, primary and secondary treatment. These categories are then further divided into the individual waste treatment processes.

Table 4 summarizes the types of industrial waste treatment employed and the effluent quality obtained by present treatment facilities in 5 representative industries. Where available, the criteria used for the design and operation of these treatment plants are given.

The types of industrial waste treatment considered in this report are divided into three categories. These categories are pre or primary treatment, secondary treatment and sludge dewatering and disposal. In most cases, the parameters of treatment efficiency are BOD and suspended solids removal. Other efficiency parameters of treatment are available in specific cases and these are indicated in the Table.

If the only type of treatment used by a particular plant is pre and/or primary treatment, these process efficiencies are indicated. When secondary treatment and/or combinations of primary and secondary treatment are used, the efficiencies listed in Table 4 are for the complete treatment system. Secondary treatment as listed in this table includes final clarification for activated sludge.

All references used in the preparation of Tables 3 and 4 are listed in the bibliography. Most of the sources of these data are from private communications.

TABLE 3

REPORTED WASTEWATER TREATMENT PROCESS EFFICIENCIES

INDUSTRY	TYPE OF TREATMENT	REMOVAL EFFICIENCIES - % SS	BOD	OTHER-AS INDICATED	NO. OF PLANTS
Pulp & Paper	Primary				
	Clarifier	65-90	15-40		5
	Secondary*				
	Activated Sludge+	75-90	81-96		7
	Aerated Lagoon	79-91	65-90		4
	Trickling Filter	-	57-90		4
Chemical	Primary (Includes Clarification, Neut.,Flotation, Coag., etc.)	90-100	4-50		5
	Secondary*				
	Activated Sludge	-	51-99		5
	Extended Aeration	83-93	80-99		6
	Aerated Lagoon	-	61-71		3
	Activated Sludge + Trickling Filters	-	72-99		3
Meat Packing	Primary				
	Anaerobic Lagoon	67-98	65-95		3
	Anaerobic Contact	90	92		1
	Screening	32	27		1
	Secondary*				
	Anae. Treatment + Facultative or Aerobic Ponds	81-98	93-99		7
Petroleum	Primary (API, Clarif., Coag., Flot., etc.)	63-75	-	27-23 COD	3
	Secondary*				
	Aerated Lagoon	-	-	50-80 COD	6
	Trickling Filter	-	-	20-92 COD 46-96 Phenol	6
	Activated Sludge	-	-	60-70 COD 85-100 Phenol	11
	Extended Aeration	-	-	50 COD	1
Dairy	Secondary*				
	Extended Aeration	neg.-81	> 90		2
	Aerated Lagoons	-	75		2
	Trickling Filter	32-91	60-71		2

+Includes contact stabilization

*Includes primary treatment when used

PRE AND/OR PRIMARY TREATMENT					SECONDARY TREATMENT					SLUDGE DISPOSAL AND DEWATERING
TYPE		TREATMENT EFFICIENCY(1)			TYPE	DESIGN CRITERIA	TREATMENT EFFICIENCY(2)			
		SS_{in} (mg/l)	SS_{out} (mg/l)	% Rem.			BOD_{in} (mg/l)	BOD_{out} (mg/l)	% Rem.	
Clarification		15,000	100-200	99	None	-	-	-	-	Builds Up in Lagoons
Clarification		-	200	-	"	-	-	500	-	N.A.
Clarif., Neut., Arsenic Removal		30	3	90	"	-	150	140	6.7	Vacuum Filter, Landfill
Neutralization, Clarif.		8,000	8	99.8	"	-	130	125	3.9	Landfill
Chlorination, Neutralization, Clarification	N.A.	-	-	-	"	-	-	-	-	Incineration
Coagulation, Ponding	N.A.	-	-	-	"	-	-	-	-	N.A.
Chrome Removal, Neut., Clarification	N.A.	-	-	-	"	-	-	-	-	Landfill
API, Lagooning		-	70	-	"	-	300	150	50	Landfill
Clarif., Neut. w/Lime		400	2,700	(-)	"	-	-	34	-	Landfill
Fat Separation, Settling		120	-	-	"	-	-	150	-	N.A.
Equal., Neut., Lagooning		6,000	0	100	"	-	-	1,370	-	Lagooning
Oxidation by Aeration		Sulfite Liquors			"	-	-	-	-	-
N.A.		N.A.	-	-	Activated Sludge	N.A.	440	5	98.8	N.A.
Nitrogen Added		0	104	(-)	" "	0.24 #BOD/#MLSS·d	2,000	25	98.7	"
N.A.		600	-	-	" "	N.A.	2,100	1,030	51	"
Neut., Clarification		100-300	100-300	0	" "	N.A.	1000-3000(3)	50-150	95	"
Grit Rem., Clarif., Nutrients		1,000	20	98	Activated Sludge + Polishing Ponds	0.57 #BOD/#MLSS·d	1,900	50	97.5	"
None		N.A.			Extended Aeration	N.A.	1,700	100	94	"
"		"			" "	"	1,950	200	89.7	"
"		576	75	87	" "	"	1,540	250	83.8	Digestion, Landfill
"		1,530	100	93.5	" "	"	1,960	24	98.7	Lagoons

SS Suspended Solids
N.A. Data Not Available
(1) Includes Removal By Clarification After Secondary Treatment if Applicable
(2) Includes BOD_5 Removal in Primary Treatment
(3) COD

Table 4
Waste Treatment Plants - Effluent Quality - Chemical Industry

PRE AND/OR PRIMARY TREATMENT					SECONDARY TREATMENT					
TYPE	TREATMENT EFFICIENCY(1)			TYPE	DESIGN CRITERIA	TREATMENT EFFICIENCY(2)			SLUDGE DEWATERING AND DISPOSAL
	SS_{in} (mg/l)	SS_{out} (mg/l)	% Rem.			BOD_{in} (mg/l)	BOD_{out} (mg/l)	% Rem.	
Equalization	700	50	93	Extended Aeration + Oxidation Ponds	N.A.	3,750	100	97.3	Aerobic Digestion + Landfill
"	600	100	83.3	Extended Aeration + Oxidation Ponds	"	2,350	75	96.8	Aerobic Digestion + Landfill
Nutrient Addition	171	76	56.5	Contact Stabilization	"	301	60	80	Landfill
Neutral., Nutrient Add. N.A.				" "	"	156	10	93.6	Thickener, Centrifuge
" " "	32	60	(-)	" "	"	114	29	74.5	N.A.
Comminutor, Nutrient Add. N.A.				Extended Aeration	"	9,800	20	99.9	Stabilization Pond
Stabilization	136	457	(-)	Aerated Lagoon	"	1,060	308	71	Landfill
Neutral., Clarification	250	65	74	" "	2.58 #BOD/#MLSS·d	465	180	61.3	Landfill
Nutrient Feed	30	60	(-)	" "	1.45 #BOD/#MLSS·d	120	42	65	N.A.
Neutral., Equalization	20-100	5-30	~57	Trickling Filters + Lagoons	N.A.	1,960	37	98.6	Landfill
Grit Rem., Equal., Neutral., Flot.	500-1200	-		Activated Sludge + Trickling Filters	5.6 #BOD/#MLSS·d 2.1 #BOD/yd^3·d	1700-2300	375-750	272	Aerobic Digestion Landfill
Neutral., Clarif. N.A.	-	-		2 Trickling Filter + Activated Sludge + Sand Filter	1.09, 0.32 #BOD/yd^3·d 0.31 #BOD/#MLSS·d	190	6.1	96.8	N.A.
N.A.	-	-	5-10	-	Activated Sludge + Trickling Filter + Ponding	N.A.	500-1400	10	99	N.A.
N.A.	N.A.	-	-	-	Facultative Ponds	"	686	186	73	Landfill + Burning
Coagulation, Neutral., Filtration - Diatomaceous Earth N.A.	-	-	-	None	"	N.A.			Ponding
Grit Rem., Neut., Coag., Clarif.	500	20-40	94	"	"	150	60	60	Vacuum Filter, Lagoon

Table 4
Waste Treatment Plants - Effluent Quality - Chemical Industry

TYPE	SECONDARY TREATMENT				PRE AND/OR PRIMARY TREATMENT				SLUDGE DEWATERING AND DISPOSAL
	DESIGN CRITERIA	TREATMENT EFFICIENCY(2)			TYPE	TREATMENT EFFICIENCY(1)			
		BOD_{in}	BOD_{out}	% Rem.		SS_{in}	SS_{out}	% Rem.	
Batch Aeration	N.A.	600	10	98.3	None	160	90	43.7	N.A.
Aerated Lagoon	N.A.	100	25	75	None	N.A.			N.A.
Lagoons w/Spray Aer.	10.5 #BOD/A·day	400	100	75	None	82	66	19.5	N.A.
Extended Aeration	0.04 #BOD/#MLVSS·day	820-620	20-220	93.3-64.9	Grit Chamber, Equalization	460-360	90-1150	81.3-neg.	N.A.
Prim. Trickling Filter Secon. Trickling Filter	16400 #BOD/A·ft·day 9840 #BOD/A·ft·day	730	210	71.3	Clarification	770	70	91	N.A.
Trickling Filter	10560 #BOD/A·ft·day	350	140	60	Clarification	190	130	31.6	Digester, Drying Beds

N.A. Data Not Available
SS Suspended Solids
(1) Includes Removal by Clarification After Secondary Treatment if Applicable
(2) Includes BOD Removal in Primary Treatment

Table 4
Waste Treatment Plants - Effluent Quality - Dairy Industry

PRE AND/OR PRIMARY TREATMENT					SECONDARY TREATMENT					SLUDGE DEWATERING AND DISPOSAL
TYPE	DESIGN CRITERIA	TREATMENT EFFICIENCY(1)			TYPE	DESIGN CRITERIA	TREATMENT EFFICIENCY(2)			
		SS_{in}	SS_{out}	% Rem.			BOD_{in}	BOD_{out}	% Rem.	
Screening	N.A.	2,780	1,890	32	None	-	1,720	1,250	27.3	N.A.
3 Anaerobic Ponds	520 #BOD/A·day	N.A.			"	-	1,430	490	65.6	N.A.
Screening, Anaer. Lagoon	4023 #BOD/A·day	2,075	685	67	"	-	2,600	530	79.5	N.A.
Anaerobic Lagoon	2919 #BOD/A·day	1650-6600	110-140	93.3-98	"	-	3300-4000	177-195	~95.6	In Lagoon
Anaerobic Contact	N.A.	2,000	200	90	"	-	2200-2600	180-200	~92	Landfill
Anaerobic Lagoon	950 #BOD/A·day	N.A.			Recovery Pond, Aerobic Pond	N.A.	2,328	44	98	N.A.
" "	N.A.	N.A.			" " " "	N.A.	1,939	31	98.4	N.A.
" "	N.A.	N.A.			" " " "	N.A.	1,860	43	98.3	N.A.
" "	1360 #BOD/A·day	N.A.			Facultative Pond	280 #BOD/A·day	1,135	82	92.8	N.A.
Screening, Anaerobic Lagoon Grease Skimming	6180 #BOD/A·day	457	88	81	Aerobic Pond	25 #BOD/A·day	940	20	98	N.A.
Anaerobic Contact	0.156 #BOD/ft^3 day	988	23	97.7	Facultative Ponds	N.A.	1,381	26	98.1	N.A.
Balancing Tank, Digester	0.035 #BOD/ft^3 day	3,020	80	97.3	Facultative Ponds	N.A.	1,765	18	99	N.A.

NA Data Not Available
(1) Includes Clarification After Secondary Treatment if Applicable
(2) Includes Removal in Primary Treatment

Table 4
Waste Treatment Plants - Effluent Quality - Meat Packing Industry

PRE AND/OR PRIMARY TREATMENT					SECONDARY TREATMENT					SLUDGE DEWATERING AND DISPOSAL
TYPE	TREATMENT EFFICIENCY(1)				TYPE	DESIGN CRITERIA	TREATMENT EFFICIENCY(2)			
	Charac.	Infl.	Effl.	% Rem.			COD_{in}	COD_{out}	% Rem.	
API, Clarif., Neutral.	SS	100	50	50	Aerated Lagoons + Holding Ponds	N.A.	300	235	21.7	Landfill
API, Coag., Clarif.	SS	109	38	65.1	None	-	977	259	73.5	Vacuum Fil., Incineration
API, Coag., Flotation	SS	65	24	63.1	None	-	380	114	70	" "
API, Hay Filter	SS	120	30	75	None	-	380	300	26.7	Lagoons, Landfill
API, Flotation	N.A.				None	-	N.A.	-	-	Vacuum Filtration
API	Oil	197	22	88.7	Aerated Lagoon	N.A.	467	146	68.8	N.A.
API, Flotation	SS	-	20	-	" "	"	600	300	50	"
None	N.A.				" "	"	855	175	79.5	"
"	Oil	61	-	-	" "	"	534	210	60.7	"
"	N.A.				" "	"	976	300	69.2	"
API, Aeration + Equal.	SS	-	15-32	-	Trickling Filter + Holding Basin, Sand Filter		1200-2350	127-154	92	"
N.A.	Phenol	8.5	0.7	91.8	Trickling Filter	55 #COD/1000 ft^3·d	384	151	60.7	"
"	"	55	2.1	96.2	" "	42 #COD/1000 ft^3·d	287	109(3)	-	"
"	"	15	4.0	73.4	" "	159 #COD/1000 ft^3·d	280	230	17.8	"
"	"	237	53	77.7	" "	126 #COD/1000 ft^3·d	2,020	1,138	43.6	"
"	"	15	8	46.6	" "	15 #COD/1000 ft^3·d	122(3)	48	-	"
"	Oil	20	9	55	Activated Sludge	0.125 #BOD/#MLVSS·d	111(3)	34(3)	67.4(3)	"
"	"	50	2	96	" "	1.43 #COD/#MLVSS·d	250	100	60	"
"	Phenol	85	3	96.5	" "	0.4 #COD/#MLVSS·d	272	-	-	"
"	"	0.7	0.1	85.7	" "	N.A.	157	54	65.5	"
"	"	190	0.3	99	" "	0.22 #COD/#MLSS·d	1,000	330	67	"

SS Suspended Solids
N.A. Data Not Available
(1) Includes Removal by Secondary Treatment if Applicable
(2) Includes Removal by Primary Treatment
(3) BOD_5

Table 4
Waste Treatment Plants - Effluent Quality - Petroleum Industry

PRE AND/OR PRIMARY TREATMENT					SECONDARY TREATMENT					SLUDGE DEWATERING AND DISPOSAL
TYPE	TREATMENT EFFICIENCY				TYPE	DESIGN CRITERIA	TREATMENT EFFICIENCY			
	Charac.	Inf.	Effl.	% Rem.			COD_{in}	COD_{out}	% Rem.	
N.A.	Phenol	125	0.2	99.8	Activated Sludge	N.A.	N.A.	-	-	N.A.
"	"	800	10	98.7	" "	"	4,000	1,200	65	"
"	"	600	5	99	" "	"	N.A.	-	-	"
"	"	2	0.1	95	" "	0.65 #BOD/#MLSS·day	109(3)	60(3)	45	"
"	"	30	0.5	98.3	" "	N.A.	700	250	64.3	"
API, Flotation	SS	-	12	-	" "	"	70(3)	14(3)	80	"
Chemical	SS	-	20	-	Extended Aeration	0.1 #BOD/#MLSS·day	600	300	50	"

Table 4
Waste Treatment Plants - Effluent Quality - Petroleum Industry

PRE AND/OR PRIMARY TREATMENT					SECONDARY TREATMENT					SLUDGE DISPOSAL
TYPE	TREATMENT EFFICIENCY(1)				TYPE	DESIGN CRITERIA	TREATMENT EFFICIENCY(2)			
		SS_{in} (mg/l)	SS_{out} (mg/l)	% Rem.			BOD_{in} (mg/l)	BOD_{out} (mg/l)	% Rem.	
Clarifier		1,260	350	72	None	-	250	150	40	N.A.
"		325	98	70	"	-	175	149	14.9	N.A.
"	N.A.	-	-	-	"	-	-	-		Centrifuge, Incineration
"		1,243	393	68.3	"	-	302	200	33.1	Vacuum Filter
Clarifier + Screens		227	19	91.7	"	-	273	218	20.1	Centrifuges, Landfill
Clarifier		350	30	91.4	"	-	145	50	65.5	Vacuum Filter
"	N.A.	-	-	-	"	-				Centrifuge
"	N.A.	-	-	-	"	-				Centrifuge
"	N.A.	-	-	-	"	-				Vacuum Filter
"		505	124	77.5	Activated Sludge	0.19 lb BOD/lb MLSS·d	274	33	88	N.A.
N.A.	N.A.	-	-		" "	N.A.	500	125	75	N.A.
N.A.		800	100	87.5	" "	0.13 lb BOD/lb MLSS·d	180	20	89	N.A.
N.A.		1,050	108	89.6	" "	N.A.	260	36	86	Vacuum Filter, Landfill
N.A.		1,000	250	75	" "	"	320	60	81.3	" " "
N.A.	N.A.	-	-	-	" "	"	350	18	95	N.A.
Clarifier		570	87	84.9	Aerated Lagoon + Trickling Filter + Final Aeration	1600 lb BOD/Acre·day	655	60	90.9	Landfill
Clarifier		350	32	90.8	Aerated Lagoon	N.A.	200	50	75	None
"		95	20	79	" "	"	200	15	92.5	Sludge Lagoons
"		1,200	150	87.5	" "	"	250	90	64	N.A.
"	N.A.	-	-	-	" "	"	350	77	78	

SS Suspended Solids
N.A. Data Not Available
(1) Includes Clarification After Secondary Treatment if Applicable
(2) Includes BOD Removal in Primary Treatment

Table 4
Waste Treatment Plants - Effluent Quality - Pulp and Paper Industry

PRE AND/OR PRIMARY TREATMENT					SECONDARY TREATMENT					SLUDGE DISPOSAL
TYPE	TREATMENT EFFICIENCY(1)				TYPE	DESIGN CRITERIA	TREATMENT EFFICIENCY(2)			
		SS_{in} (mg/l)	SS_{out} (mg/l)	% Rem.			BOD_{in} (mg/l)	BOD_{out} (mg/l)	% Rem.	
N.A.	N.A.	-	-	-	Trickling Filter	N.A.	288	29	90	N.A.
N.A.	N.A.	-	-	-	Trickling Filter	N.A.	218	28	87.2	N.A.
N.A.	N.A.	-	-	-	Trickling Filter	N.A.	252	30	88.2	N.A.
Clarifier	N.A.	-	-	-	Trickling Filter	37 lb BOD/1000 ft^3	306	130	57.5	Thickener, Vacuum Filter, Landfill
Clarifier	N.A.	-	-	-	Contact Stabilization	N.A.	350	14	96	N.A.

N.A. Data Not Available
(1) Includes Removal by Clarification After Secondary Treatment if Applicable
(2) Includes BOD_5 Removal in Primary Treatment

Table 4
Waste Treatment Plants - Effluent Quality - Pulp and Paper Industry

CAPITAL AND OPERATING COSTS OF REPRESENTATIVE INDUSTRIAL WASTEWATER TREATMENT PLANTS

Capital and operating costs of representative wastewater treatment plants in several industrial categories were obtained from replies to questionnaires, from engineering reports and from published data in the literature. The data have generally been reported in classifications of pre or primary treatment, secondary or biological treatment and sludge handling and disposal.

Figures 3-7 give the capital costs for the construction of various types of industrial waste treatment processes correlated to the volume of wastewater flow treated. The cost data is in thousands of dollars per million gallons of flow and is corrected to a 1966 Engineering News Record index of 970.

Figure 3 shows the capital cost - waste flow relationship for activated sludge treatment for all of the industries from which data were obtained. Two of the chemical waste treatment plants without primary treatment fell close to the other data, which included primary treatment plus activated sludge treatment. This indicates that in many cases preliminary treatment is a minor cost consideration in the construction of activated sludge plants provided that extensive primary or pre-treatment is not required. Sludge disposal may add significantly to the overall cost of treatment. Two pulp and paper mill facilities, which are shown in Figure 3 employed vacuum filtration to dewater the primary and secondary sludge. This caused the unit construction costs for these plants to be considerably greater than the costs for two other plants treating pulp and paper wastes which did not have sludge dewatering facilities. One refinery employed primary treatment consisting of an oil separator and dissolved air flotation which increased the overall plant capital cost as shown in Figure 3.

The effect of influent BOD concentration on the cost relationship can be seen in Figure 3. More data will be required to definitely establish the effect of organic loading on the construction costs of activated sludge plants.

Capital cost data for aerated lagoons treating all types of industrial wastes are presented in Figure 4. This relationship includes the costs of primary treatment. Three reported data points fall below the average line representing this relationship. The two points with waste flows between 3 and 4 MGD denote two plants, one chemical and one refinery, in which existing facilities were used for the aeration basins, so that the only aeration and hydraulic equipment costs were included in the capital outlay. The pulp and paper plant with a waste flow of about 9.5 MGD was new construction and no facilities for sludge disposal were provided.

In general, for the same waste flow the capital cost of treatment by aerated

lagoons is 40 per cent of that for activated sludge, not considering extensive sludge disposal facilities.

The capital costs for treating chemical wastes by extended aeration are shown in Figure 5. A good correlation was obtained between cost and wastewater flow for these data. This would further indicate that wastewater volume rather than influent BOD is the primary factor determining capital costs for extended aeration treatment. This observation seems reasonable since the detention time required to oxidize the biological solids accumulated in the process is relatively long in any case.

Primary treatment costs in the pulp and paper industry are shown in Figure 6. The spread in capital cost can be attributed to the wide range in solids loadings encountered in these facilities. Two sludge dewatering systems are represented; vacuum filtration and centrifugation. The primary treatment costs are approximately the same for both.

Figure 7 shows the variation in capital cost with wastewater flow for aerated lagoon treatment of pulp and paper mill wastes. The capital costs include primary treatment and sludge disposal with the exception of one plant which had no provisions for sludge disposal.

Additional construction cost data which could not be correlated with wastewater flow is given in Appendix C-1. Most of the capital and operating costs were obtained from private sources. Data from the published literature is referenced in Table C-1.

Table 5 summarizes operating costs for municipal and industrial waste treatment processes. The operating costs are expressed in dollars/MG and dollars/1000 lb. pollutant, where the pollutant may be expressed either as COD, BOD, or suspended solids.

Operating costs vary considerably from one industry to another and even within an industry. This is primarily due to the pretreatment and final solids disposal required and to the procedures of costing and bookkeeping employed by the plant. For example, a chemical plant employs activated sludge to treat its wastes at a cost of $1580/MG or $100/1000 lb. COD while it only costs about $100/MG to treat municipal sewage employing the same process. This cost differential is due to the pH adjustment and equalization required for the chemical waste. In some cases where chemical pre-treatment is required, a greater variation and a generally higher operating cost can be expected for the treatment of industrial wastes in comparison to municipal wastewater.

The detailed operating costs of pretreatment, secondary treatment, and solids disposal involved in the treatment of industrial wastes, wherever the data is available, is indicated in Appendix C-2.

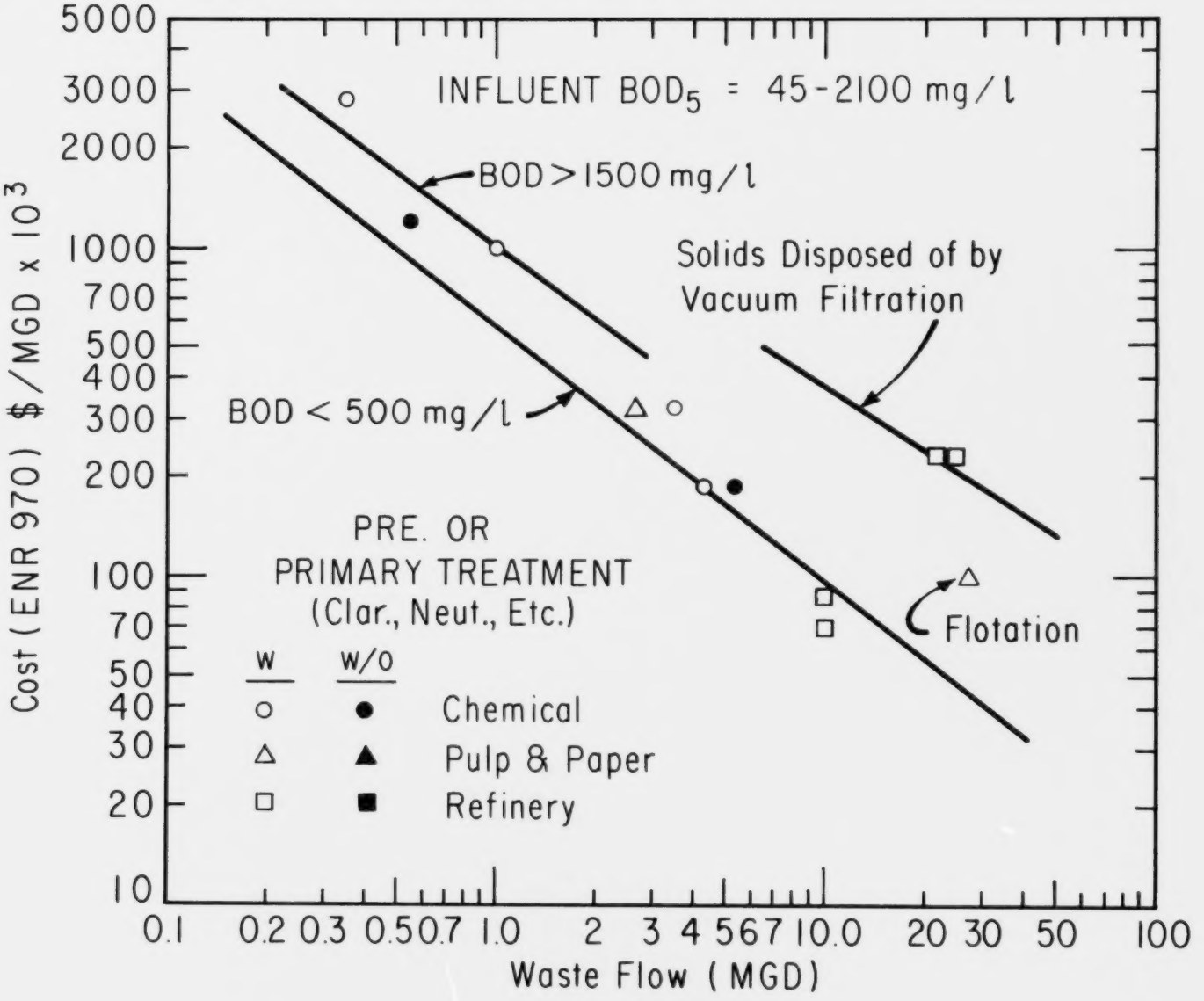


Figure 3

Capital Costs - Activated Sludge Treatment - All Industries

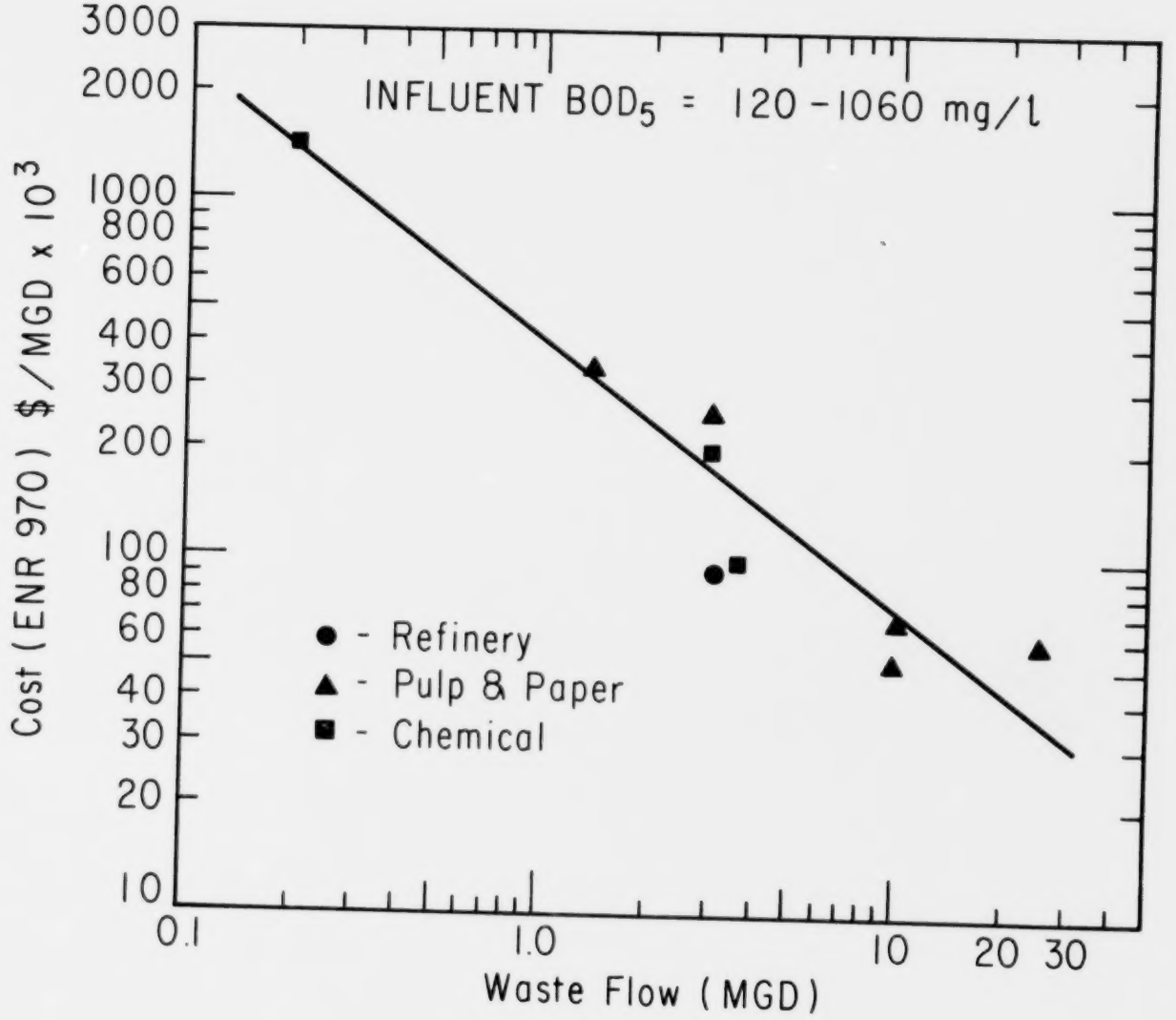


Figure 4
Capital Cost - Aerated Lagoon Treatment - All Industries
(Including Primary Treatment)

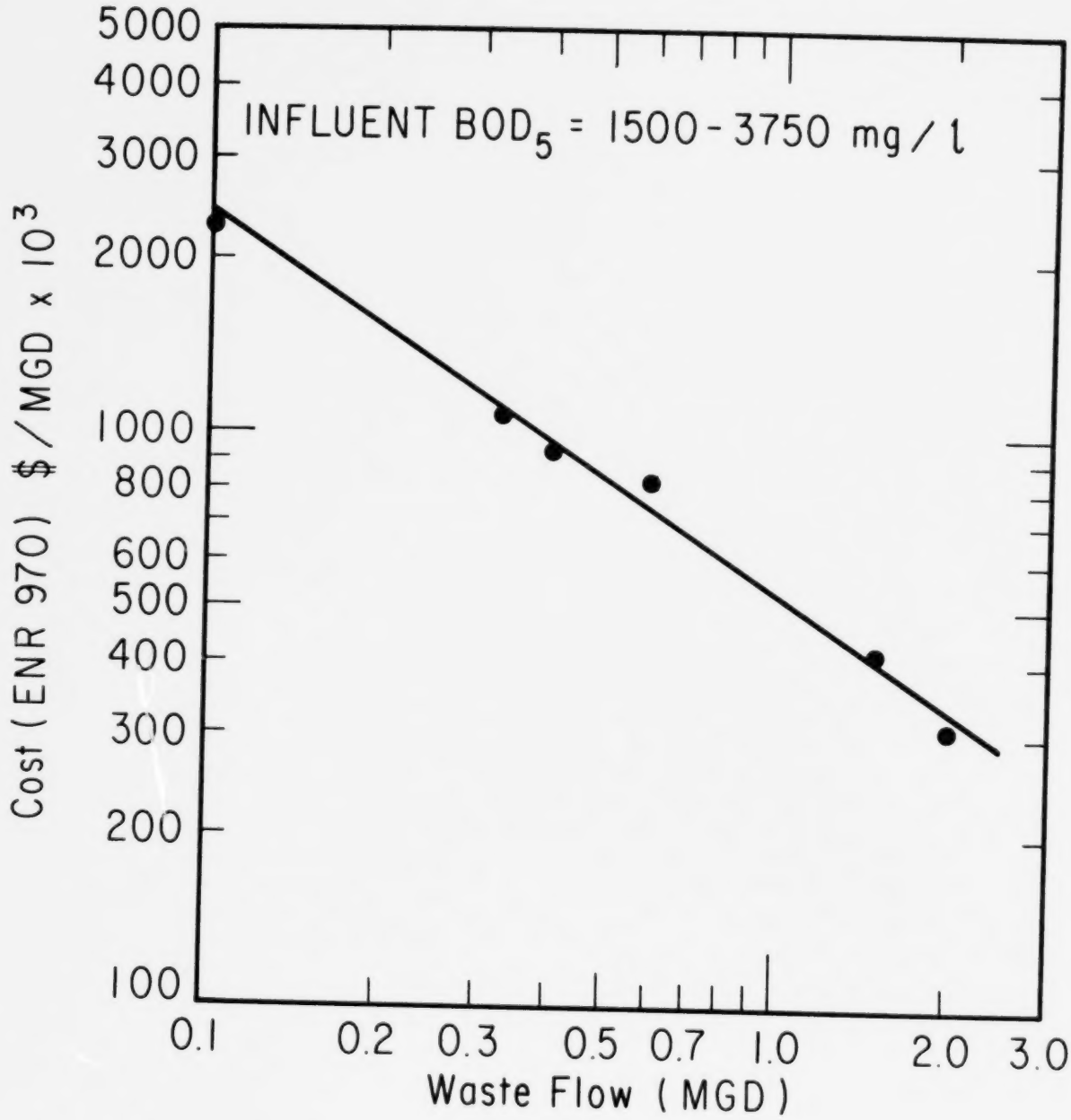


Figure 5
Cost vs Flow - Extended Aeration - Chemical Wastes

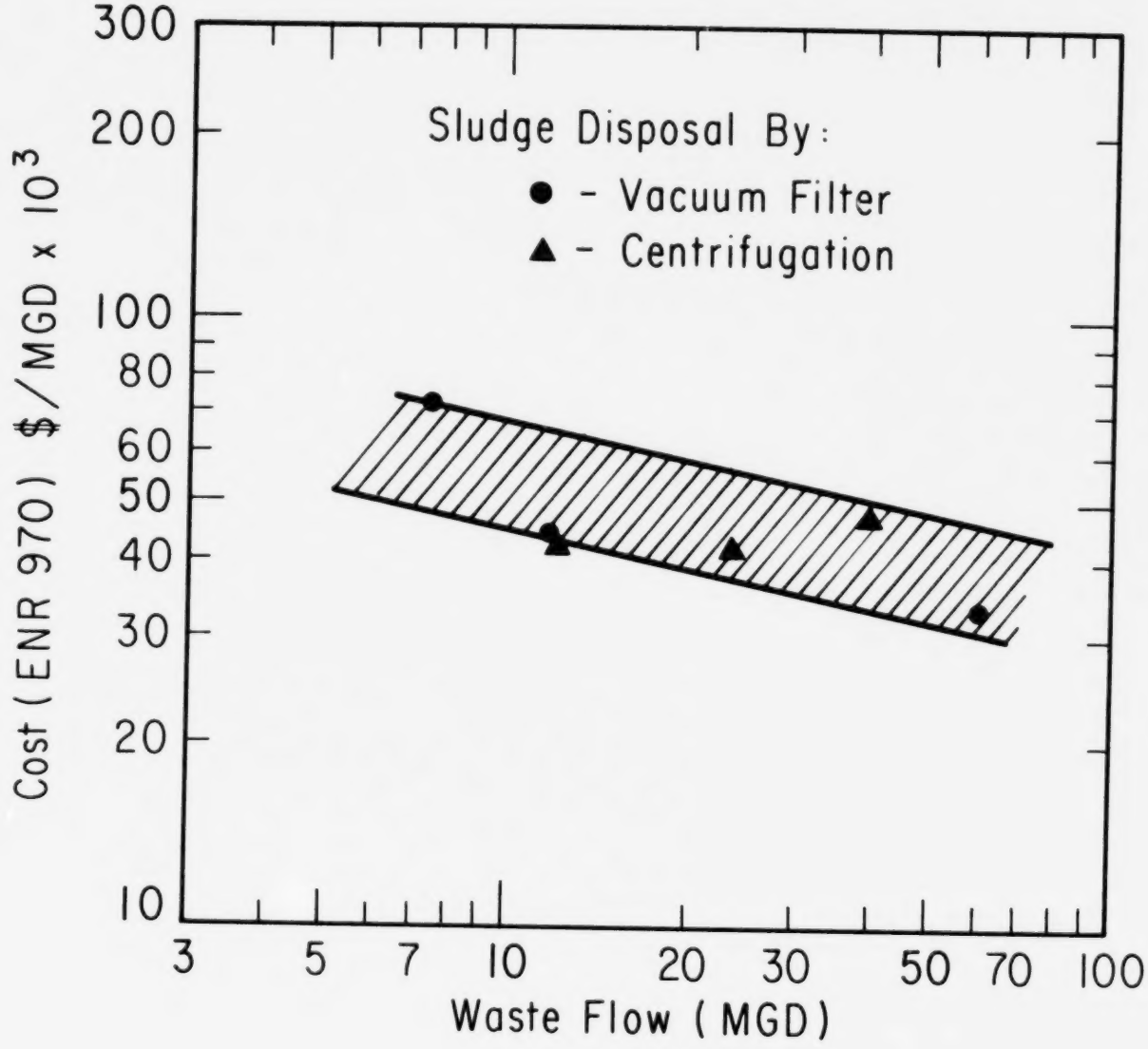


Figure 6
Cost vs Flow - Primary Treatment - Pulp and Paper Industry

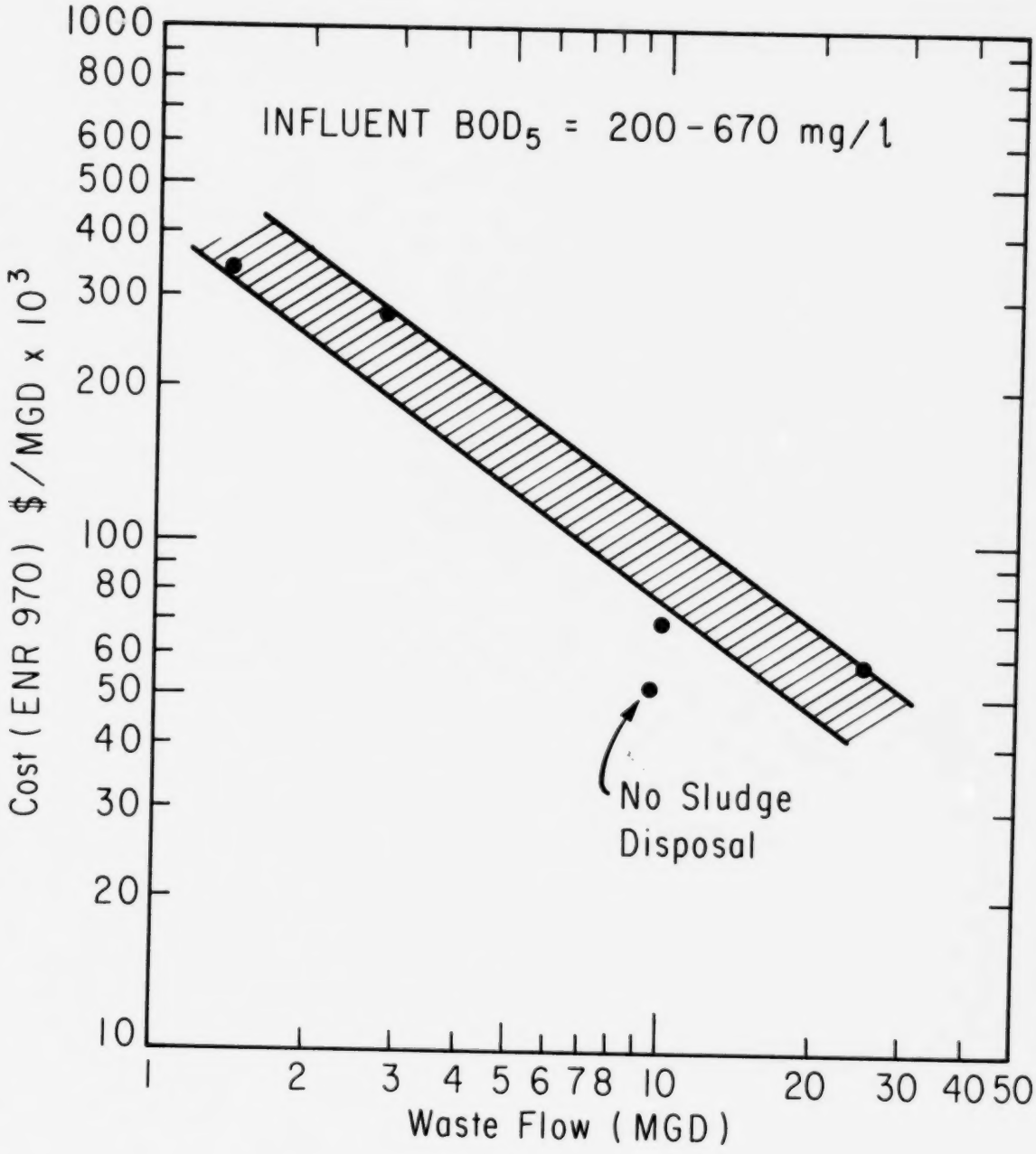


Figure 7
Cost vs Flow - Aerated Lagoon Treatment - Pulp and Paper Industry
(Includes Primary Treatment and Sludge disposal)

TABLE 5

WASTE TREATMENT PLANT - OPERATING COSTS

EXISTING INDUSTRIAL AND MUNICIPAL FACILITIES

INDUSTRY	NO. OF PLANTS	TYPE OF TREATMENT	DAILY OPERATING COST (Exclusive of Amortization) $/MG	$/1000 lbs Pollutant	SOLIDS DISPOSAL
Refinery	4	Primary Treatment	126-160	26-150[3]	V.F. Land Fill, Incineration
		Secondary Treatment			
	1	Activated Sludge	161	292[3]	Land Fill
	1	Aerated Lagoon	22	9[3]	
	1	Extended Aeration	28	14[3]	Holding Pond
Pulp & Paper	1	Primary Treatment	13	29[1]	Centrifuge-Land Fill
		Secondary Treatment			
	2	Activated Sludge	43-57	20-31[1]	V.F.-Land Fill
	4	Aerated Lagoon	6-101	4-96[1]	Lagooning
	1	T. F.	65	80[1]	Unknown
Meat Packing	3	Anaerobic Contact or Anaerobic Lagoon	57-130	7-31[1]	Lagooning
Chemical	11	Primary Treatment	11-1540	3-40[2]	Land Fill, Incineration, V. F. Lagooning
		Secondary Treatment			
	4	Aerated Lagoon	31-1160	6-477[1]	Land Fill
	5	Extended Aeration	221-276	7-734[1]	Land Fill, Lagoon
	2	Contact Stabilization	16-211	23-106[1]	Land Fill
	1	Activated Sludge	1580	100[1]	
	2	T. F.	780-2050	49-3750[1]	Lagooning
	2	T. F. - Act. Sludge	334-378	28-245[1]	Land Fill, Sand Filter
	1	Facultative Pond	163	39[1]	Burning
Municipal Sewage		Primary Treatment	19-62		
		Secondary Treatment			
		Activated Sludge	33-147		
		T. F.	21-110		
		High Rate T. F.	14-195		

(1) BOD_5

(2) SS

(3) COD

PROJECTED OPTIMIZED SOLUTION FOR EVALUATION OF INDUSTRIAL WASTE TREATMENT COST AND EFFLUENT QUALITY

This section of the report suggests a method for developing industrial waste treatment design criteria and associated effluent quality for various industrial categories. Construction costs on a unit process basis for varying degrees of effluent quality can also be developed for each industry. It was not possible in the time and scope of this report to fully develop the parameters and information needed to project detailed relationships. It is felt, however, that the information is available for this purpose.

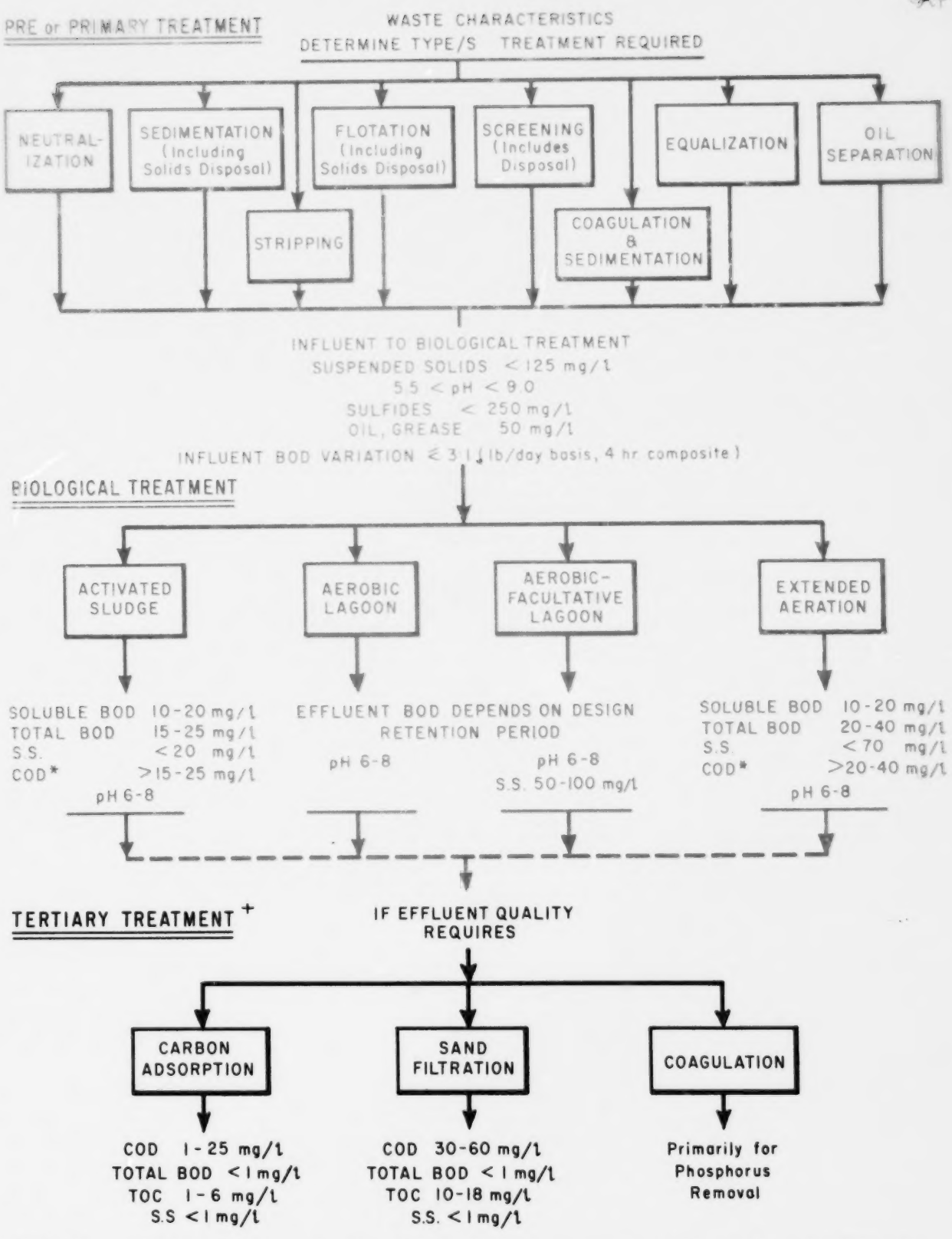
The suggested procedure for each industrial category is as follows:

1. Select the average waste flow and loading for the plants falling within a particular industrial category.
2. Extrapolate the values to the future design condition to establish the average flow and loading for the category, (i.e. 20 years hence).
3. Determine the statistical variation of flow and loading within a specific industrial plant in the category.
4. Select the effluent quality desired, i.e. BOD, COD, N, P., etc.
5. Determine pre or primary treatment requirements.
6. Develop alternate secondary treatment criteria.
7. Design sludge handling and disposal system.
8. Develop costs for alternate system designs.
9. Prepare unit cost vs effluent quality curve (see Figure 9).

Each of the aforementioned steps in the suggested procedure is detailed in the following discussion.

Determination of Waste Characteristics

Statistical plots of the type developed in the first section of this report are used to obtain the most probable characteristics of the wastewater from a given industrial category per unit of production. These statistical plots give the variation in waste characteristics between plants in the same industrial category. The changes are due to variations in production processes, in-plant control and water reuse practice. It might be expected that as more emphasis is placed on water quality, water reuse, and improved in-plant control, a decrease in the magnitude of waste flows and loading characteristics will be observed. These decreases will tend to flatten the slope of the statistical plots, pivoting about a low value which would represent maximum practical water reuse and in-plant control practices. For example, in a particular industrial category a study of present industrial practice may indicate that the 10 per cent frequency represents near optimum operation with respect to wastewater flow per unit of production. Future projections of wastewater flow would approach this value as an average with a decreased statistical distr bution around the average.



*The COD, which includes the non-biodegradable fraction, can assume any value above the total BOD value.

+The effluent qualities given are for domestic sewage.

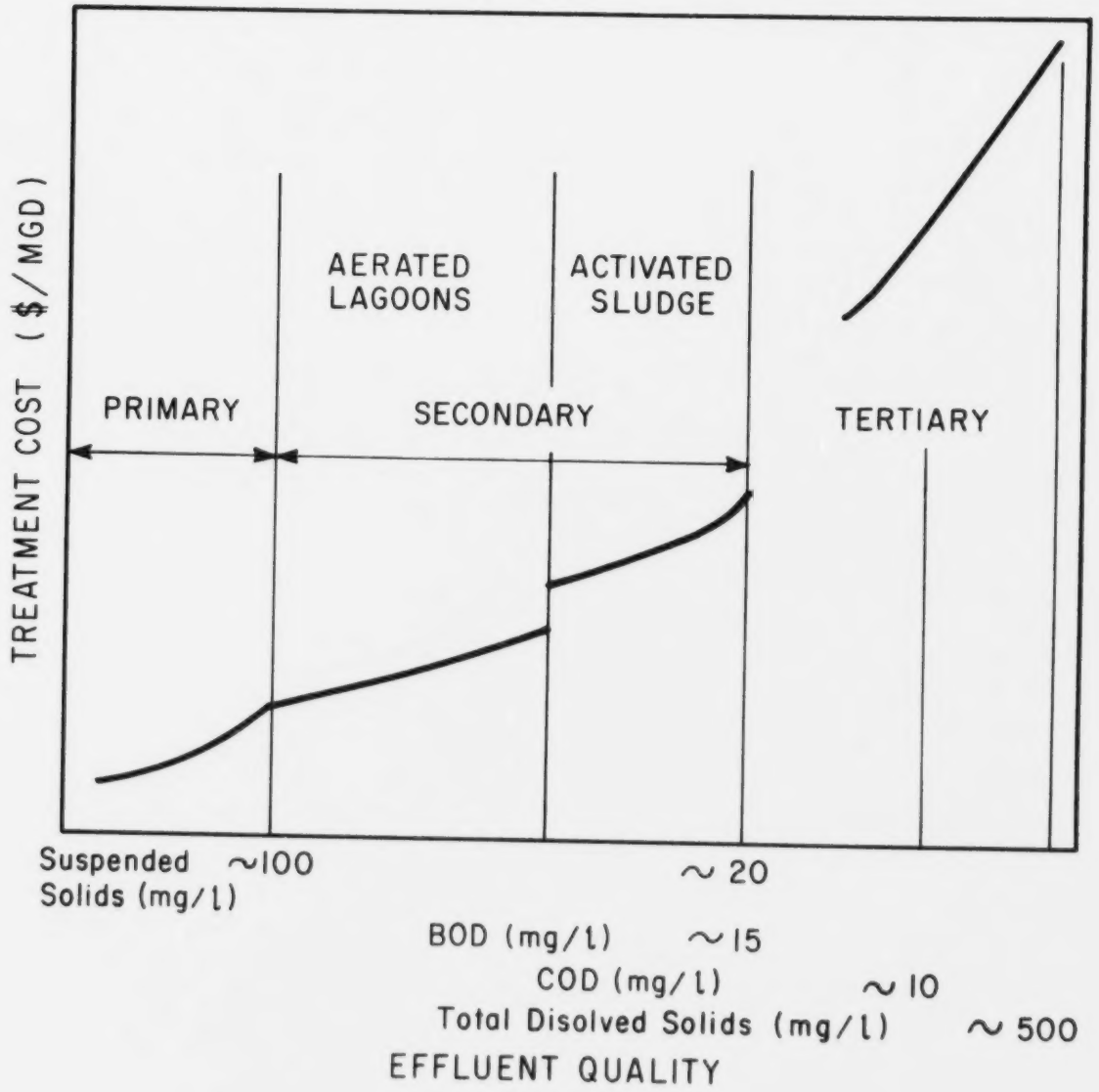


Figure 9

Typical Effluent Quality-Cost Analysis Relationship for a Particular Industrial Category and Wastewater Flow

Similar plots could be estimated for significant wastewater characteristics.

It is appreciated that this procedure does not consider significant changes in the manufacturing processes.

In any one plant there will also be a statistical variation in waste flow and characteristics. This variation is significant when considering waste treatment plant design and operation. The magnitude of the variation within a plant will depend on the process operations contributing to the waste and the diversity of products manufactured. Design of the waste treatment processes must be based on these statistical variations so that the effluent quality will not be adversely affected by the changes in the wastewater characteristics.

The effect of quality and quantity variation on the process design of the activated sludge process is shown in Table 6.

Waste Treatment Process Selection

After the waste flow and characteristics are determined, the alternate treatment processes can be selected and designed, based on the desired effluent quality. The flowsheet (Figure 10) and example problem illustrate a method which can be used in the optimized solution.

Several combinations of the various unit treatment processes can be used to give the desired effluent quality for the industrial waste to be treated. These different designs are compared on a cost basis to determine the optimum. The proposed procedure for cost estimation will be discussed later in this report.

Before an organic waste can be treated biologically, it may be necessary to give it pre or primary treatment. The influent to the biological processes should generally conform to the following maximums as design guidelines.

1. Suspended solids $<$ 125 mg/l
2. Acidity or alkalinity[1]
3. Sulfides $<$ 250 mg/l
4. Oil, grease, flotables $<$ 50 mg/l
5. Influent BOD loading (lb/day) based on a four-hour composite should be less than 3:1 variation[2]
6. Removal of heavy metals

If these criteria are not satisfied by the raw waste, one or more of the pre or primary treatment processes shown in the flow diagram of this report should be used prior to biological treatment of the wastewater.

---

[1] The biological system has the capacity to neutralize acidity or alkalinity. The maximum acidity or alkalinity will depend on the BOD removed in the process.

[2] Further research may modify this value. Variations greater than that suggested should be preceded by an equalization basin.

TABLE 6

EFFECT OF WASTEWATER VARIATION ON PROCESS DESIGN OF BIOLOGICAL TREATMENT - ACTIVATED SLUDGE[1]

	FREQUENCY USED, %
AERATION TANKS	50[2]
AERATION SYSTEM	90
SLUDGE HANDLING SYSTEM	50

[1] After equalization if used

[2] Depends on allowable variation in effluent quality, in some cases may use 90% frequency value.

OPTIMIZED SOLUTION

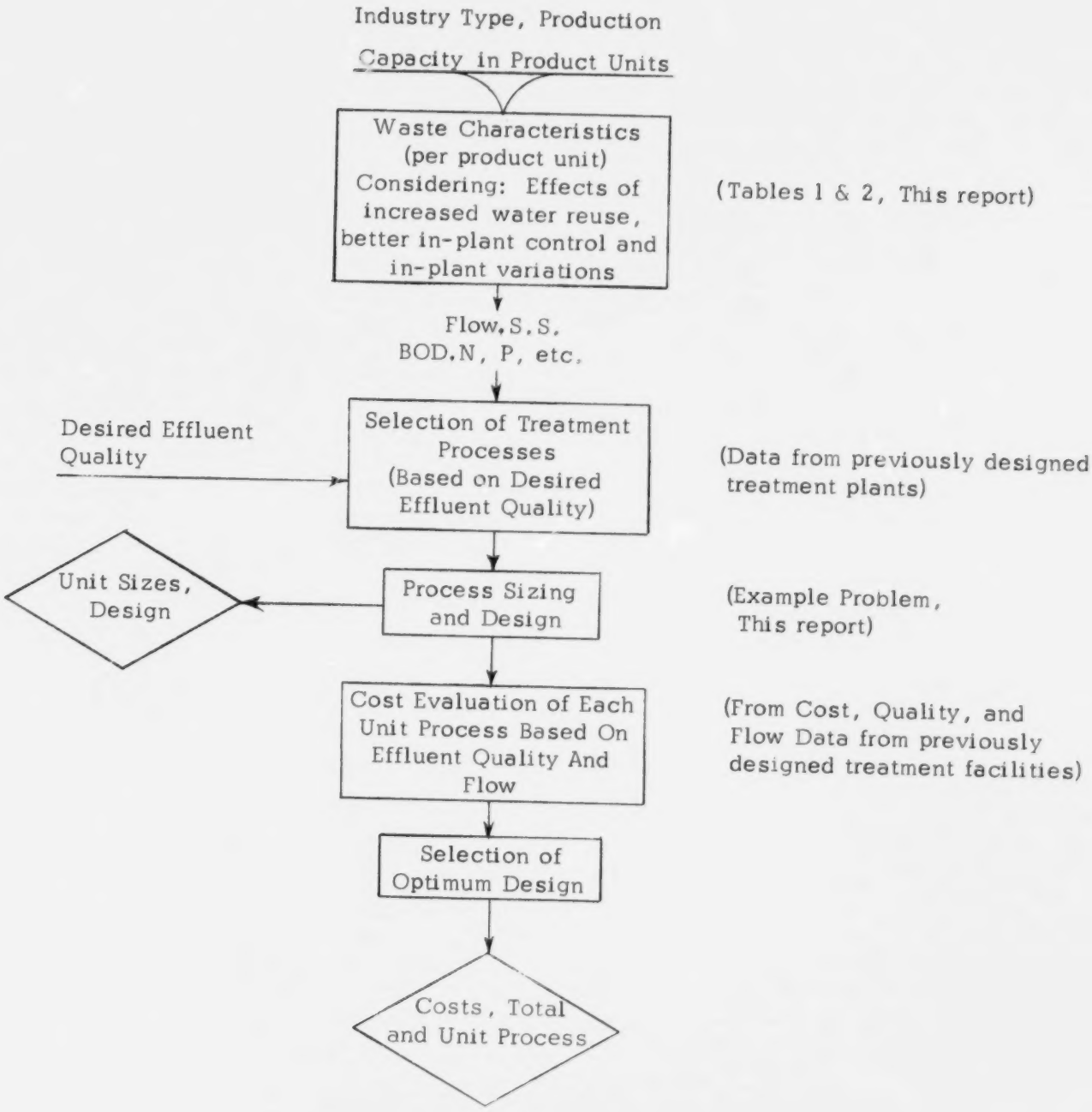

Industry Type, Production Capacity in Product Units
Waste Characteristics (per product unit) Considering: Effects of increased water reuse, better in-plant control and in-plant variations
(Tables 1 & 2, This report)
Flow, S.S. BOD, N, P, etc.
Desired Effluent Quality
Selection of Treatment Processes (Based on Desired Effluent Quality)
(Data from previously designed treatment plants)
Unit Sizes, Design
Process Sizing and Design
(Example Problem, This report)
Cost Evaluation of Each Unit Process Based On Effluent Quality And Flow
(From Cost, Quality, and Flow Data from previously designed treatment facilities)
Selection of Optimum Design
Costs, Total and Unit Process

FIGURE 10

Four types of biological treatment process will be considered. These are:

1. Activated Sludge
2. Extended Aeration
3. Aerobic Lagoon
4. Aerobic-Facultative Lagoon

Table 7 summarizes the design parameters of these biological treatment systems.

After selection of the possible alternate biological treatment processes for the wastewater to be treated, preliminary design calculations can be developed using appropriate coefficients as shown in the design equations summarized in Table 10.

Values of the coefficients are presently available for many industrial waste categories and more data is being obtained all the time. Sufficient data is available at this time for preliminary estimation of treatment costs for various levels of effluent quality.

In order to illustrate the use of these relationships, a design example is presented.

Discussion

The general treatment scheme shown in the flow diagram of Figure 8 can be applied to all of the organic industrial wastes considered in this report. The characteristics of the raw waste from each industry will determine the type of pre or preliminary treatment required. Standards of effluent quality will determine the alternate types of biological treatment used and will also indicate whether tertiary treatment is required. Alternate methods of sludge handling and disposal can be similarly calculated.

Cost Estimation

After selection and design of the alternate waste treatment systems the cost of the unit processes can be estimated and the total cost for each system computed. From this cost analysis the optimum design to give the desired effluent quality can be selected.

Cost relationships can be developed on a unit process basis, similar to the method used by Smith[1] for municipal waste treatment processes. Operational costs can also be estimated on a unit process basis as shown in Table 7.

Table 7 gives a list of the unit processes for primary, secondary and tertiary treatment and the bases to be used for developing cost relationships.

---

[1] Smith, Robert, Federal Water Pollution Control Administration, Cincinnati, Ohio (106)

TABLE 7

SUGGESTED BASES FOR
COSTING UNIT PROCESSES

TYPE OF TREATMENT	DESIGN BASIS	CONSTRUCTION COST BASIS	OPERATIONAL COST BASIS
Neutralization	Waste Flow	$/MGD	Acidity or Alkalinity
Screening	Waste Flow	$/MGD	-----
Sedimentation	Overflow Rate	$/ft^2	----
Flotation	Air/Solids Ratio	$/ft^2	Air/Solids Ratio
Oil Separation	Overflow Rate	$/ft^2	-----
Coagulation (Must be followed by clarifier)	Waste Flow	$/MGD	Chemical Requirements
Equalization[1]	Waste Flow	$/MGD	-----
Stripping (Gas and Solvent)	Waste Flow	$/MGD	Air or Stream Usage

[1]Depends on subsequent treatment units

TABLE 7

SUGGESTED BASES FOR
COSTING UNIT PROCESSES

TYPE OF TREATMENT	DESIGN BASIS	CONSTRUCTION COST BASIS	OPERATION COST BASIS
Activated Sludge (Aeration Tanks)	Organic Loading and Waste Flow	$/1000 ft^3	-----
Final Clarifier	Waste Flow	$ ft^2	-----
Extended Aeration	Organic Loading	$/1000 ft^3	-----
Aerobic-Facultative Lagoon (Aerated Lagoon)	Waste Flow and Organic Loading	$/1000 ft^3	-----
Sludge Thickener	Mass Loading	$/$ft^2$	-----
Aeration System	Organic Loading	$/hp	hp used
Vacuum Filtration	Filter Loading	$/$ft^2$	-----
Centrifugation	Flow and Solids Loading	$/Gpm	hp used

TABLE 8

COEFFICIENTS REQUIRED FOR BIOLOGICAL TREATMENT DESIGN

COEFFICIENT	PURPOSE
k - BOD removal rate coefficient	Aeration basin volume
a - Sludge yield coefficient	Sludge disposal requirement
b - Sludge auto oxidation rate	Sludge disposal requirement
a' - Oxygen requirements	Aeration system design
b' - Endogenous respiration rate	Aeration system design

Continuing and Future Investigations

The procedure presented in this report should serve as the basis for developing a computerized solution relating effluent quality to treatment cost. It will be necessary to process considerably more information before the model can be completed.

Additional information is required for a more complete statistical analysis of industrial waste characteristics. A method must be projected to predict the effects on industrial waste flow and characteristics of increased water reuse and better in-plant control. The effect of in-plant variations on flow and characteristics must also be estimated for each industry.

Additional information is required on the unit treatment processes to be used in the waste treatment plant design and costing. Relationships between effluent quality, flow and unit process costs must be developed. The effluent quality obtained from various unit processes treating industrial wastewaters must be tabulated for use in treatment process selection. The data presented in this report for costs and effluent quality is continuously being supplemented with additional data from private communications with industry.

TABLE 9

SUMMARY OF DESIGN RELATIONSHIPS

The basic relationships applicable to the design of biological waste treatment facilities are summarized below:

(1) BOD or COD Removal in a Completely Mixed Basin; Aerobic or Anaerobic

$$\frac{S_a - S_e}{X_a t} = KS_e \qquad (1)$$

(2) Sludge Yield

$$\Delta X_v = S_o + aS_r - bX_v \quad \text{(conventional systems; aerobic or anaerobic)} \qquad (2)$$

$$\Delta X_v = S_o + aS_r - bX_d \quad \text{(total oxidation system; aerobic)} \qquad (2a)$$

(3) Equilibrium Solids in an Aerobic Lagoon or Anaerobic Flow-through system

$$\frac{S_o + aS_r}{(1 + bt)} = X_a \qquad (3)$$

(4) Sludge Age

$$G = \frac{X_v}{\Delta X_v} = \frac{X_v}{aS_r - bX_v} \qquad (4)$$

(5) Oxygen Requirements (Aerobic Systems)

$$O_2 = a'S_r + b'X_v \quad \text{(conventional systems)} \qquad (5)$$

$$O_2 = a'S_r + b'X_d \quad \text{(total oxidation systems)} \qquad (5a)$$

(6) Nutrient Requirements

$$\text{Nitrogen (N)} = 0.12\,\Delta X_v + 1.0 \text{ mg/l} \qquad (6)$$

$$\text{Phosphorus (P)} = 0.02\,\Delta X_v + 0.5 \text{ mg/l} \qquad (6a)$$

(7) Organic Loading

$$F = \frac{24\,S_a}{X_a t} \qquad (7)$$

TABLE 10

SUMMARY OF BIOLOGICAL OXIDATION DESIGN PARAMETERS

PROCESS	ACTIVATED SLUDGE	EXTENDED AERATION	AEROBIC LAGOON	AEROBIC-FACULTATIVE LAGOON
Loading Range lbs BOD/day/lb MLSS	0.3-0.6[1]	0.1-0.25	≈ 2.0	≈ 2.0
Aeration Solids mg/l	2000-5000[2]	3500-5000[2]	1/2 BOD_{REM}	50-100[3]
BOD Removal Eff.[4] % (overall)	90-95	85-90	50-60	80-90
Effluent				
Soluble BOD, mg/l	10-20	10-20	-[5]	-[5]
Total BOD, mg/l	15-25	20-40	-[5]	-[5]
Suspended Solids, mg/l	< 20	< 70		50-100
Sludge Yield lbs/lb BOD removed	≈ 0.30	≈ 0.10	≈ 0.50	-
O_2 Requirement % of BOD removed	90-95	120	75	≈ 100-120
Minimum Aeration				
Power Level	≈ 0.4 ft/sec[6]	≈ 0.4 ft/sec[6]	≈ 0.4 ft/sec[6]	≈ 8 HP/MG
Temperature Coefficient θ	≈ 1.0	≈ 1.0	≈ 1.035	≈ 1.065-1.085

(1) Higher loadings will frequently result in filamentous and non-flocculent sludge growth.

(2) Upper level limited by concentration and rate of return sludge.

(3) Related to influent BOD and suspended solids and to aeration power level and mixing intensity.

(4) Includes both soluble and suspended BOD.

(5) Depends on design retention period.

(6) Bottom velocity in aeration basin.

EXAMPLE: ALTERNATE DESIGNS FOR AEROBIC BIOLOGICAL TREATMENT

Flow = 0.75 MGD

Influent BOD_5 = 650 mg/l

k_1 = 0.002

a = 0.55

b = 0.10/day

a' = 0.40

b' = 0.14/day

Influent COD = 765 mg/l

A. AEROBIC LAGOON

The required detention period for an effluent soluble BOD_5 of 50 mg/l can be computed from the relationship developed by combining equations (1) and (3). This process will ultimately be modified to extended aeration when higher effluent quality is required.

$$t, \text{ days} = \frac{1}{24aKs_e - b}$$

For a = 0.55 and b = 0.15/day, the required detention period is:

$$t = \frac{1}{(24 \times 0.55 \times 0.002 \times 50 - 0.10)} = 0.9 \text{ days} \simeq 22 \text{ hrs.}$$

The Required Aeration Tank Volume is:

V = 0.9 (0.75) = 0.675 MG

The equilibrium volatile solids in the lagoon is computed from Equation 3.

$$X_v = \frac{S_o + aS_r}{1 + bt}$$

$$= \frac{0 + 0.55(600)}{1 + 0.1 \times 0.9}$$

$$= 303 \text{ mg/l}$$

The total suspended solids will be

$$X_a = \frac{X_v}{\text{volatile fraction}}$$

assume: volatile fraction = 80%

$$X_a = \frac{303}{0.80}$$

$$= 379 \text{ mg/l}$$

The BOD_5 of the mixed effluent will be:

$$BOD_5 = 50 + 0.3 \times 379 = 163 \text{ mg/l}$$

where 0.3 converts effluent SS to BOD_5 in mg/l.

Oxygen requirements

The estimated oxygen requirements are:

$$O_2/\text{day} = (0.40 \times 600 \times 0.75 \times 8.34) + (0.14 \times 308 \times 0.675 \times 8.34) \quad \text{(Eq. 5)}$$

$$= 1500 + 243$$

$$= 1743 \text{ lbs/day} = 72.6 \text{ lb/hr}$$

Using aerators which transfer 2.5 lb O_2/HP-hr @ 20°C at 0 mg/l D.O.
C_s = 8.5 mg/l @ 20°C, α = 0.8 and C_L = 1.5 mg/l

$$\text{lbs } O_2/\text{HP-hr} = N = N_o\left(\frac{8.5 - 1.5}{9.0}\right) \quad 0.8 \times 1.0 = 0.62\ N_o$$

$$HP = \frac{72.6}{2.5(0.62)} = 47$$

and the operating power level is:

$$\frac{47}{0.675 \times 1000} = 0.070 \text{ HP/1000 gal}$$

∴ Ample for mixing and oxygen diffusion

B. ACTIVATED SLUDGE

Assume a mixed liquor volatile suspended solids concentration of 3000 mg/l and a loading F, of 0.5 lb BOD_5/lb MLVSS day for optimum floc density.

The required detention time from Eq. 7 is:

$$t = \frac{24S_a}{X_a F} = \frac{24(650)}{3000(0.5)}$$

$t = 10.4$ hrs $= 0.43$ days

The aeration basin volume is:

$V = 0.75(0.43) = 0.322$ MG

From equation (1)

The effluent BOD_5 (soluble, after clarification) is:

$$S_e = \frac{S_a}{1 + 24KX_a t} = \frac{650}{1 + 24 \times 0.002 \times 3000 \times 0.43}$$

$S_e = 10$ mg/l

Oxygen Requirements (Assume 75% of volatile solids are degradable)

lbs O_2/day $= (0.40 \times 640 \times 0.75 \times 8.34) + (0.14 \times 0.322 \times 3000 \times 8.34 \times 0.75)$

$= 1600 + 846 = 2446$ lbs O_2/day $= 102$ lbs O_2/hr

The required aeration horsepower is (assuming 0.015 HP/1000 gal and $N_o = 2.5$ lbs O_2/HP-hr)

$$HP = \frac{102}{0.62(2.5)} = 66$$

$$\frac{66}{322} = 0.205 \text{ HP}/10^3 \text{ gal}$$

Excess Sludge (based on 85% volatile solids)

lbs VSS/day = [0.55 x 640 x 0.75 x 8.34] - [0.1 x 0.322 x 3000 x 8.34 x 0.75]

= 2200 - 606 = 1594 lbs/day

or T S S $= \frac{1594}{0.85}$ = 1880 lbs/day

C. AEROBIC - FACULTATIVE LAGOON

The volatile solids level in the lagoon is assumed to be 50 mg/l. Field experience has indicated that the expected effluent suspended solids concentration will range from 50-100 mg/l depending on the power level in the lagoon.

The retention period for an effluent soluble BOD of 30 mg/l will be:

$$t = \frac{Sr}{24KX_v Se} = \frac{620}{24 \times 0.002 \times 50 \times 30} \quad \text{(Eq. 1)}$$

t = 8.6 days

The aeration basin volume will be

V = 0.75(8.6) = 6.45 MG

Oxygen Requirements

lb O_2/day = [0.40 x 620 x 0.75 x 8.34]= 1550 lbs/day = 64.6 lb/hr

ASSUME N_o = 2.5 lb O_2/HP-hr.

$$HP = \frac{64.6}{2.5(0.62)} = 41.7$$

and the power level will be

$$\frac{41.7}{6.45 \times 1000} = 0.0065 \text{ HP/1000 gal}$$

Too low - below 0.08 HP/1000 gal needed for ample oxygen mixing and diffusion.

Use ——— 6.45(1000)0.008 = 51.7 HP

Excess Sludge (85% volatile solids basis) from Eq. 2

lbs VSS/day = [0.55 x 620 x 0.75 x 8.34] - [0.1 x 6.45 x 50 x 8.34 x 0.75]

= 2140 - 202 = 1938 lbs/day

or TSS = $\frac{1938}{0.85}$ = 2280 lbs/day

The Sludge Age = $\frac{0.75 \times 8.34 \times 620}{2280}$ = 1.7 days

D. EXTENDED AERATION

$$X_{av} = \frac{a_o Sr}{fb}$$

where a_o = conversion to degradable sludge and f = fraction of volatile solids which are degradable: $a_o = 0.48$, $f = 0.7$

$$X_{av} = \frac{0.48(635)(0.75)(8.34)}{(0.70)(0.10)}$$

= 27200 lbs

if the sludge is 85% volatile

Total MLSS = $\frac{27200}{0.85}$ = 32000 lbs

at 4000 mg/l MLSS, the aeration volume is:

$$V = \frac{32000}{4000 \times 8.34} = 0.96 \text{ MG}$$

the organic loading is = $\frac{635(0.75)(8.34)}{27200}$ = 0.146 lb BOD/lb MLVSS·day

Aeration Requirements

lbs O_2/day = $0.4[635 \times 0.75 \times 8.34] + 1.4 \times 0.48 [635 \times 0.75 \times 8.34]$

= 1590 + 2670 = 4260 lbs/day = 177 lbs/hr

Using N_o = 2.60 lbs O_2/HP-hr

$$HP = \frac{177}{2.6(0.62)} = 111 \text{ HP}$$

Power Level:

$$\frac{111}{0.96(1000)} = 0.116 \text{ HP/1000 gal}$$

Assuming 50 mg/l suspended solids in the effluent and for an endogenous sludge, a mg/l BOD_5/mg/l SS ratio of 0.15, the total effluent BOD_5 is:

Total Effluent BOD = 15 mg/l + 50(0.15) = 22 mg/l

The excess sludge = $[0.146 \times 0.55] + [635 \times 8.34 \times 0.75] - [50 \times 0.5 \times 8.34]$ (Effluent Loss)

= 320 - 209 = 111 lbs/day

The Sludge Age = $\frac{32000}{111}$ = 288 days

TABLE 11

DESIGN PARAMETERS - EXAMPLE PROBLEM

PARAMETER	ACTIVATED SLUDGE	EXTENDED AERATION	AEROBIC LAGOON	AEROBIC FACULTATIVE LAGOON
lb BOD/lb MLVSS day	0.5	0.15	22	1.78
Aeration Volatile Solids mg/l	3000	3400	303	50
BOD Removal Efficiency, %	98.5	96.6	74	93
Effluent				
Soluble BOD mg/l	10	15	50	30
Total BOD mg/l	14	22	163	45
S.S. mg/l	< 20	50	379	50
COD mg/l	125	-	278	145
non-biodegradable COD mg/l	115	115	115	115
Sludge Yield lb/lb BOD removed	0.398	0.028	0.633	-
O_2 Requirement % BOD removed	61.2	107	46.5	40.1
Aeration HP	66	111	47	52
Power Level-HP/1000 gal	0.205	0.116	0.07	0.008
Sludge Age, days	2.55	288	2.15	1.7

BIBLIOGRAPHY

1. Amberg, H. R. "Aerated Stabilization of Board Mill White Water," Proc. 20th Ind. Waste Conf., Purdue Univ., 1965.

2. Anderson, C. O. "Oil Refinery Waste Treatment as practiced by Rock Island Refinery Corp. at Indianapolis, Ind." Ind. Wastes, 2, Nov.-Dec., 1957.

3. Bamman, R. K. "Paper Making, Coating, and Decoating Waste Treatment Plant at the Ohio Division, Champion Papers Inc.," Proc. 17th Ind. Waste Conf., Purdue Univ., 1962.

4. Bentley, W. D. "Pretreatment of Industrial Wastes at Dallas, Texas," Jour. Water Pol. Control Fed., 35, Aug., 1963.

5. Berger, Herbert F. "Survey of Solids Removal Practices in Southern Kraft and Newsprint Mills," Technical Bulletin No. 120, National Council for Stream Improvement, 1959.

6. Besselievre, E. B. Industrial Waste Treatment, New York, McGray-Hill Book Co., Inc., 1952.

7. "Biological Treatment of Petroleum Refinery Wastes," New York, American Petroleum Institute: Division of Refinery, 1963.

8. Bishop, F. W., and J. W. Wilson. "Southland Paper Mills Waste Treatment and Disposal," Sew. and Ind. Wastes, 26, Dec., 1954.

9. Black, Hayes H., and Gerald N. McDermott. "International Waste Guide-Beet Sugar," Sew. and Ind. Wastes, 24, Feb., 1952.

10. Bolton, J. M. "Waste from Poultry Processing Plants," Proc. 13th Ind. Waste Conf., Purdue Univ., 1958.

11. Bubbis, N. S. "Industrial Waste Control in Metropolitan Winnipeg," Industrial Water and Wastes, 7, Nov.-Dec., 1962.

12. Bueltman, C. G. "Bio-Oxidation of Brewery Wastes," Proc. 14th Ind. Waste Conf., Purdue Univ., 1959.

13. Brandon, T. W. "Industrial Wastes--Waste Waters from Beet Sugar Factories, Their Treatment and Disposal," International Sugar Journal, 49, 1947.

14. Bryan, Edward H. "Two-Stage Biological Waste Treatment." Industrial Water and Wastes, 8, Jan.-Feb., 1963.

15. Cawley, William A., and Richard W. Brouillette. "Polyvinyl Chloride for Trickling Filters." Industrial Water and Wastes, 7, July-Aug., 1962.

16. Cawley, W. A., and Virgil A. Minch, "Treatment of Paper Mill Wastes," Proc. 1st Sanitary Eng. Conf., Vanderbilt Univ., 58, May-June, 1962.

17. Coerver, J. F. "Anaerobic and Aerobic Ponds for Packinghouse Waste Treatment in Louisiana," Proc. 19th Ind. Waste Conf., Purdue Univ., 1964.

18. Coughlan, F. P., Jr. "Design and Operation--Activated Sludge Plant for Scott Paper Co.," Technical Association of the Pulp and Paper Industry, 146, No. 5.

19. Coughlan, F. P., and A. E. Sparr. "Design and Early Operation Experience of Activated Sludge Plant for Combined Treatment of Pulp, Paper, and Industrial Wastes," Proc. 16th Ind. Waste Conf., Purdue Univ., 1961.

20. Coster, A. D., "Water Pollution Control," Proc. Master Brewers Assoc. of America, 1960.

21. Crawford, S. C. "Spray Irrigation of Certain Sulfate Pulp Mill Wastes," Sew. and Ind. Wastes, 30, Oct. 1958.

22. Davis, R. W., J. A. Biehl, and R. M. Smith. "Pollution Control and Waste Treatment at an Inland Refinery," Proc. 19th Ind. Waste Conf., Purdue Univ., 1964.

23. Dickinson, D., "Effluents from the Industrial Preparation of Food," Water Pollution Control, (Journal of the Instit. of Water Poll. Control), 66, 1967.

24. Dickinson, D., "The Origin, Treatment and Disposal of Effluents in the Food Canning and Freezing Industries," Waste Treatment, P. Isaac, Ed., Pergamon Press, London, 1960.

25. Dornbush, James N., and John R. Andersen. "Lagooning of Livestock Wastes In South Dakota," Proc. 19th Ind. Waste Conf., Purdue Univ., 1964.

26. Dorris, Troy C., B. J. Copeland, and Donald Patterson. "The Case for Holding Ponds...Two Refineries Find Them Highly Effective," Oil and Gas Journal, 59, Oct. 30, 1961.

27. Dorris, Troy C., Don Patterson, and B. J. Copeland. "Oil Refinery Effluent Treatment in Ponds." Jour. Water Poll. Control Fed., 35, July, 1963.

28. Drummond, R. M. "Pulp and Pulp Waste Reduction by Mill Improvement," Sew. and Ind. Wastes, 26, May, 1954.

29. Eckenfelder, W. W., and D. J. O'Connor. Biological Waste Treatment, New York, Pergamon Press, 1961.

30. Eckenfelder, W. Wesley, Jr. "Factors Affecting the Aeration Efficiency of Sewage and Industrial Wastes," Sew. and Ind. Wastes, 31, Jan. 1959.

31. Eckenfelder, W. Wesley, and Edwin Barnhart. "Synthetic Detergent Removal from Laundry Wastes," Water and Sewage Works, 108, Sept., 1961.

32. "Efficiency of Various Methods of Treatment--Milk Plant Wastes--N. Y. State." New York State Water Pollution Control Board, Research Report #2, 1959.

33. Eick, J. F. "Tannery Waste Disposal by Spray Irrigation." Ind. Wastes, 1, Nov.-Dec., 1956.

34. Elkin, H. F. "Condensates, Quenches, and Wash Waters as Petrochemical Waste Sources," Sew. and Ind. Wastes, 31, July, 1959.

35. Evers, D., "Carpet Manufacturing Effluents and Their Treatment," Jour. and Proc. Sewage Purif., Part 5, 1966.

36. Fair, Gordon M., and John C. Geyer. Water Supply and Waste-Water Disposal, John Wiley and Sons, Inc., New York, N. Y., 1954.

37. Fleming, George S. "Treatment and Re-Use of Water in Beet Sugar Manufacturing," Sew. and Ind. Wastes, 24, Nov. ,1952.

38. Flynn, John M. "Launderette Waste Treatment System," Water and Sewage Works, 110, Feb., 1963.

39. Fowler, James A. "The Wate-Disposal Program of the Sinclair Refining Co., East Chicago, Illinois," Proc. Fifth Ind. Waste Conf., Purdue Univ., 1949.

40. Francis, R. L. "Characteristics of Potato Flake Processing Wastes," Jour. Water Pollution Control Fed., 34, March, 1962.

41. "Fruit Processing Industry," U. S. Public Health Service, No. 952, 1962.

42. Gehm, H. W., and W. A. Maggio. "Conservation of Water in the Kraft Pulp and Paper Industry," Technical Association of the Pulp and Paper Industry, 37, No. 3.

43. Greene, G. "Experimental Work on the Treatment of the British Celanese Ltd. Trade Waste," Jour. & Proc. Sewage Purif., London, Part 2, 1957.

44. Greer, B. A., R. E. Gillespie, and P. C. Trussell. "Biochemical Oxygen Demand of Total Effluent from Full-Bleach Kraft Mill," Technical Assoc. of the Pulp and Paper Industry, 39, No. 8.

45. Giles, R. N. "A Rational Approach to Industrial Waste Disposal Problems," Sew. and Ind. Wastes, 24, Dec., 1952.

46. Gurnham, C. F. (ed.) Industrial Wastewater Control. New York and London, Academic Press, 1965.

47. Hale, F. "Sources of BOD in Brewery Wastes," Sew. and Ind. Wastes, 25, Oct., 1953.

48. Harris, A. J. "Water Pollution Control Activities of the Central Ontario Lakeshore Refineries," Jour. Water Poll. Control Fed., 35, Sept.,1963.

49. Hahn, Roy W., Jr., and Frank D. Callcott. "A Comprehensive Survey of Industrial Waste Pollution in South Carolina," Proc. 20th Ind. Waste Conf., Purdue Univ., 1965.

50. Haseltine, T. R. "Tannery Wastes Treatment with Sewage at Williamsport, Pennsylvania," Sew. and Ind. Wastes, 30, Jan., 1958.

51. Hedgepeth, L. L., A. J. Gabaccia, C. G. Mauriello, and H. W. Senn. "Planning a Waste Survey," Sew. and Ind. Wastes, 30, Jan., 1958.

52. Heynike, J. J. C. "Water and Effluents in the Iron and Steel Industry," Jour. and Proc. Sewage Purif., Part 3, 1965.

53. Hickerson, R. C., and E. K. McMahon. "Spray Irrigation of Wood Distillation Wastes," Jour. Water Poll. Control Fed., 32, Jan., 1960.

54. Hill, Kenneth V. "Designing a Combined Treatment Works for Municipal Sewage and Packinghouse Wastes at Austin, Minnesota," Proc. 12th Ind. Wastes Conf., Purdue Univ., 1958.

55. Holderby, J. M., and W. A. Moggio. "Utilization of Spent Sulfite Liquor," Jour. Water Poll. Control Fed., 32, Feb., 1960.

56. Hopkins, Glen J., Joe K. Neel, and Francis L. Nelson. "Evaluation of Broad Field Disposal of Sugar Beet Wastes," Sew. and Ind. Wastes, 28, Dec., 1956.

57. Jackson, C. J. "The Treatment of Distillery and Antibiotics Wastes," Waste Treatment, P. Isaac, ed., Pergamon Press, London, 1960.

58. Jaquett, Zachary, and Dr. N. C. Burbank, Jr. "American Cyanamid Simplifies Sludge Handling from Lagoons," Industrial Water and Wastes, 8, July-Aug., 1963.

59. Jenkins, S. H. "Analystical Tests in Relation to the Discharge of Trade Effluents to Sewers," Waste Treatment, P. Isaac, ed., Pergamon Press, London, 1960.

60. Jones, E. L., T. A. Alspaugh, and H. B. Stokes. "Aerobic Treatment of Textile Mill Waste," Jour. Water Poll Control Fed., 34, May, 1962.

61. Kalda, D. C. "Treatment of Sugar Beet Wastes by Lagoons," Proc. 13th Ind. Waste Conf., Purdue Univ., 1958.

62. Keller, Arthur G., and H. K. Huckabay. "Pollution Abatement in the Sugar Industry of Louisiana," Jour. Water Poll. Control Fed., 32, July, 1960.

63. Lambden, A. E. "The Fisions Pest Control Limited Effluent Plant," Jour. and Proc. Sewage Purif., Part 2, 1959.

64. Lawton, G. W., L. E. Engelbert, and G. A. Roblick. "Effectiveness of Spray Irrigation as a Method for the Disposal ot Dairy Plant Wastes," Univ. of Wisconsin, 1960.

65. Lawton, G. W., George Breska, L. E. Engelbert, G. A. Rohlich, and Nandor Porges, "Spray Irrigation of Dairy Wastes," Sew. and Ind. Wastes, 31, Aug., 1959.

66. Lebo, James E. and Hassler, J. W. "Trickling Filter Studies in Treating Pulp and Paper Mill Wastes," Sew. and Ind. Wastes, 29, Feb. 1957.

67. Lewis, A. W. "Tidewaters Delaware Refinery Waste Control and Treatment," Sew. and Ind. Wastes, 31, April,1959.

68. Ludden, John, Jr., and John F. Vogler. "Pollution Abatement Through Water Conservation--a Symposium. Part III--Water Conservation in a Chemical Plant," Sew. and Ind. Wastes, 24, Nov., 1952.

69. Luley, Howard G., B. Victor Pfeiffer, et. al. "Industry's Idea Clinic," Jour. Water Poll. Control Fed., 37, April, 1965.

70. Madera, V. "Applications of Biochem. Reduction for Industrial Wastes," Jour. and Proc. Sewage Purif., Part 5, 1966.

71. Maehler, Claude Z., and Arnold E. Greenberg. "Identification of Petroleum Industry in Groundwaters," Jour. Water Poll. Control Fed., 34, Dec., 1962.

72. Mau, G. E. "Pilot-Plant Studies of Refinery Wastes Treatment on Trickling Filters," Sew. and Ind. Wastes, 26, Oct., 1954.

73. Maxwell, B. Rands, and D. E. Copper. "Development and Operation of a Low Cost Anaerobic Plant for Meat Wastes," Proc. 21st Ind. Waste Conf., Purdue Univ., 1966.

74. McCarthy, Joseph A. "Characteristics and Treatment of Wool Dyeing Wastes," Sew. and Ind. Wastes, 22, Jan., 1950.

75. McCord, James C. "Design and Operation of a Phenol Recovery Plant," Sew. and Ind. Wastes, 26, Aug., 1954.

76. McPhee, Walter T., and Arnold R. Smith. "From Refinery Wastes to Potable Water," Civil Engineering, 31, Sept., 1961.

77. Meighen, A. D. "Spray Irrigation of Strawboard Wastes," Industrial Water and Wastes, 6, Sept.-Oct., 1961.

78. Mitchell, R. D. "Joint Approach to Treatment of Domestic and Industrial Wastes at Battle Creek, Michigan," Jour. Water Poll.Control Fed., 35, April, 1963.

79. Murphy, Nelson F., and Dale R. Gregory. "Removal of Color from Sulfate Pulp Wash Liquors," Proc. 19th Ind. Waste Conf., Purdue Univ., 1964.

80. Neale, Alfred T. "Pulp and Paper Mill Wastes in Washington," Ind. Wastes, 3, March-April, 1958.

81. Nemerow, N. L. Theories and Practices of Industrial Waste Treatment. Addison-Wesley Publishing Co., Reading, Mass., 1963.

82. Newton, D. "Brewery Waste BOD," Wastes Engineering, 27, Oct., 1956.

83. Nicholai, A. L., W. W. Eckenfelder, and D. G. Gardner. "Effluent Treatment Study for a Rubber Research Laboratory," Ind. Wastes, 1, March-April, 1956.

84. O'Connell, Wm. J. "California Fruit and Vegetable Cannery Waste Disposal Practices," Jour. Water Poll. Control Fed., 29, March, 1957.

85. Okun, D. A., et. al. "A Review of the Literature of 1962 on Wastewater and Water Pollution Control," Jour. Water Poll. Control Fed., 35, June, 1963.

86. O'Rourke, J.T., and H. D. Tomlinson. "Effects of Brewery Waste on Treatment," Ind. Water and Wastes, 7, Sept.-Oct., 1962.

87. Pearman, Ben V., Jr., and Oliver B. Burns, Jr. "Activated Sludge Treatment of Kraft and Neutral Sulfite Mill Wastes," Sew. and Ind. Wastes, 29, Oct., 1957.

88. Peters, J. C. "Technical and Biological Aspects of Waste Water Treatment at Bowningtown Paper Co.," Technical Association of the Pulp and Paper Industry, 42, No. 12.

89. Pettit, Grant A. "Mill Scale Wastes," Ind. Wastes, 3, Nov.-Dec., 1958.

90. Porges, Ralph, and W. W. Towne. "Wastes from the Potato Chip Industry," Sew. and Ind. Wastes, 31, Jan., 1959.

91. Porges, Ralph. "Wastes from the Processing of Corn Ships," Jour. Water Poll. Control Fed., 32, Feb., 1960.

92. Prather, B. V. "Chemical Oxidation of Petroleum Refinery Wastes," Proc. 13th Ind. Waste Conf., Oklahoma Water and Poll. Control Assoc., ed. A. F. Gaudy, Jr., 77, Nov., 1962.

93. Puvsell, W. L., and R. B. Miller. "Waste Treatment of Skelly Oil Company's El Dorado, Kansas Refinery," Proc. 16th Ind. Waste Conf., Purdue Univ., 1961.

94. Rollag, D. A., and J. N. Dornbush. "Anaerobic Stabilization Pond Treatment of Meat Packing Wastes," Proc. 21st Ind. Waste Conf., Purdue Univ., 1966.

95. Rostenbach, Royal E. "Status Report on Synthetic Rubber Wastes," Sew. and Ind. Wastes, 24, Sept., 1952.

96. Rowan, P. P., Jenkins, K.L., and Howells, D. H. "Estimating Sewage Treatment Plant Operation and Maintenance Costs," Jour. Water Poll. Control Fed., 33, Feb., 1961.

97. Rudolfs, W. (ed.) Industrial Waste Treatment. New York, Reinhold Publishing Co., 1953.

98. Ryckman, Dr. D. W., Prof. E. D. Edgerley, and Dr. N. C. Burbank. "Evaluation and Abatement of Industrial Waste Problems," Industrial Water and Wastes, 7, July-Aug., 1962.

99. Schneider, R. "Waste Disposal at a Modern Brewery," Sew. and Ind. Wastes, 22, Oct., 1950.

100. Schraufnagel, F. H. "Dairy Wastes Disposals by Ridge and Furrow Irrigation," Proc. 12th Ind. Wastes Conf., Purdue Univ., 1957.

101. Sellers, William W. "Caterpillar Tractor Plant Solves Water Problems," Ind. Wastes, 1, May-June, 1956.

102. Sen, B. P., and T. R. Bhaskaran. "Anaerobic Digestion of Liquid Molasses Distillery Wastes," Jour. Water Poll. Control Fed., 34, Oct., 1962.

103. Simonsen, R. N. "Pollution Abatment Through Water Conservation, How Four Oil Refineries Use Water," Sew. and Ind. Wastes, 24, Nov., 1952.

104. "A Simplification of Textile Waste Survey and Treatment," Report by Wesleyan University, July, 1959.

105. Singleton, K. G. "The Treatment of Contaminated Waste Water from Synthetic Resin Manufacture," Jour. and Proc. Sewage Purif., Part 6, 1965.

106. Smith, Arthur. "Waste Disposal by Textile Plants," Jour. Water Poll. Control Fed., 37, Nov., 1965.

107. Smith, J. M. "The Treatment of Effluent from a Poultry Packing Factory," Jour. and Proc. Sewage Purif., Part 2, 1966.

108. Smith, Robert. "Construction Cost for Conventional Sewage Treatment Processes," July, 1965.

109. Souther, R. H., and T. A. Alspaugh. "Current Research on Textile Waste Treatment," Sew. and Ind. Wastes, 30, Aug., 1958.

110. Souther, R. H., and T. A. Alspaugh. "Textile Waste Treatment Studies," Proc. 13th Ind. Waste Conf., Purdue Univ., 1958.

111. Spade, James F. "Treatment Methods for Laundry Wastes," Water and Sewage Works, 109, March, 1962.

112. Sproul, O. J., K. Keshavan, and R. E. Hunter. "Extreme Removals of Suspended Solids and BOD in Tannery Wastes by Coagulation with Chrome Tan Dump Liquors," Proc. 21st Ind. Waste Conf., Purdue Univ., 1966.

113. Stien, J. H., F. M. Majewski, and T. Iezzi. "Waste Treatment at a Large Chemical Manufacturing Plant," Sew. and Ind. Wastes, 28, July, 1956.

114. Steffen, A. J., and M. Bedkev. "Operation of Full-Scale Anaerobic Contact Treatment Plant for Meat-Packing Wastes," Proc. 16th Ind. Waste Conf., Purdue Univ., 1961.

115. Steffen, A. J. "Stabilization Ponds for Meat-Packing Wastes," Jour. Water Poll. Control Fed., 35, April, 1963.

116. "Study of Fruit and Vegetable Processing Waste Disposal Methods in Eastern Region," Report by Manhattan College, Civil Engineering Dept., Nov., 1957.

117. "Synthetic Textile Industry," U. S. Department of Health, Education, and Welfare, No. 1320, 1965.

118. "The Tenth Ontario Industrial Waste Conference: a Staff Report," Ind. Water and Wastes, 8, Sept.-Oct., 1963.

119. Tidswell, M. A. "Experimental Purification of Sewage Containing a Large Proportion of Brewery Wastes at Burton Upon Trent," Jour. and Proc. of Sewage Purif., Part 2., 1960.

120. Van Luven, A. L. "Packinghouse Waste Treatment," Ind. Water and Waste, 5, Sept., 1960.

121. Waldichuk, Michael. "Pulp Mill Pollution in Alberni Harbor, British Columbia," Sew. and Ind. Wastes, 28, Feb., 1956.

122. Waldmeyer, T. "Treatment of Formaldehyde Waste by Activated Sludge Methods," Jour. and Proc. of Sewage Purif., Part 1, 1952.

123. Watson, C. W., Jr. "New Developments in Dairy Waste Treatment," Industrial Water and Wastes, 6, March-April, 1961.

124. Wilson, I. S. "The Treatment of Chemical Wastes," Waste Treatment, P. Isaac, ed., Pergamon Press, London, 1960.

Waste Source	Volume gpd	BOD_5 ppm	COD ppm	TOC ppm	Total N ppm	Total P as PO_4, ppm	Phenols ppm
Plastics		1,035	2,106				412
Synthetic Resins	170,000	1,400-500					50-10
Synthetic Resins	650,000	1,223	2,180				414
Pesticides	34,000	2,500-2,000					80-2,000
Mixed Organics	8,000,000	750			176	8	-
Mixed Organics	150,000	1,950	7,972		1,253	-	-
Herbicides 2,4,5-T		16,800	21,700		40	Trace	-
Herbicides 2,4-D		16,700	27,500		45	Trace	-
Petrochemical + Refinery	19,100,000	225	610	160	48	Trace	17
Citric Acid Manf.		12,000-8,000			1,500-1,400		
Formaldehyde	7,000-10,000						
Celanese-Mixed Organics	6,500,000	484			8.5-NH_3		
Synthetic Rubber	2,880,000	78					
Synthetic Rubber	2,950,000	-					
Synthetic Rubber		3,317					
Synthetic Rubber	1,930,000	23.3			3.85		
Wood Distillation for Alcohol	70,000	7,436	1,860				1,152
Soap, Detergent, Cosmetics	3,096,000	217	425				
Cyclic Organics	133,325	777	1,895				
Nylon		170	2,000		100		Synthetic Fibers 400

TABLE A-

INDUSTRIAL WASTE CH

CHEMICAL INI

l P ppm	Phenols ppm	T.S. ppm	S.S. ppm	D.S. ppm	Cl^- ppm	pH	Miscellaneous	References
	412						Formaldehyde = 121 ppm	59
	50- 10						Formaldehyde = 100-600 ppm Methanol = 400-1,000 ppm	105 105
	414						Formaldehyde = 129 ppm	59
	80-2,000			30,000-8,000			Glycollic Acid 250-2,050 ppm	63
	-							Private Comm.
	-	3,029	60		800		Oils = 547 ppm, $SO_4^=$ = 655 ppm	Private Comm.
ce	-	172,467	700		96,300		% Volatile T.S. = 10.5	Private Comm.
ce	-	167,221	348		144,000		% Volatile T.S. = 13.2	Private Comm.
ce	17	2,810	110		825			Private Comm.
		45,000 - 35,100				6 -6.5	V.S. = 34,000-22,000 ppm	70
		4,000				7.5-8.5	Formaldehyde = 2,000 ppm, Methanol = 8,000 ppm	122
			77.4			7.3		43
			79			7.6	Oils = 9 ppm	95
						8.6	Oils = 18 ppm	95
		8,736	204			4.6		83
			102					
	1,152							53
			133				ABS = 42 ppm	Private Comm.
			185					Private Comm.
	Synthetic Fibers 400	3,000	neg.		800		Oils = 45 ppm, H_2S = 12 ppm Minerals = 1,000 ppm	16

TABLE A-1

STRIAL WASTE CHARACTERISTICS

CHEMICAL INDUSTRY

Waste Source	Flow gpd	BOD_5 ppm	COD ppm	S.S. ppm	T.S. ppm	NH_3-N ppm	Org. N ppm	pH	Vol. Solids ppm	VSS ppm	References
Milk		1,752					40				65
Milk		4,310	7,800	1,040	6,490	36	144	4.8	4,740	910	65
Milk		936	1,241	619	2,653	7	36	6.4	1,240	561	65
Milk		4,790	4,570	1,025	5,450	19	151	5.6	3,800	998	65
Milk		1,280	1,703	361	2,280	15	43	6.8	1,350	303	65
Milk		1,890		560	4,516	6	73	5.7	2,698		
Seperated Whey		30,100		116	54,772	31	1,300	6.2	49,612		
Milk	13,500	600		160				11			32
Milk	64,500	720		360-460				7.4-7.6			32,123
Milk	150,000	730		770				6.8-7.6			32
Milk	151,000	400		82				7.6			32
Milk	361,000	100									

TABLE A-1

INDUSTRIAL WASTE CHARACTERISTICS

DAIRY INDUSTRY

Waste Source	BOD ppm	S. S. ppm	T. S. ppm	Total N ppm	Total P ppm	SO_4 ppm	References
Malt-Spent Wash	25,000	5,000	37,500	1,600	20	110	57
Grain-Spent Wash	10,000	5,900	20,100	450	-	150	57
Industrial Alcohol Spent Wash	15,950	6,000	70,800	1,300	300	480	57
Industrial Alcohol Plant A	48,000	6,400	110,000	2,200			57
Plant B	8,700	2,500	28,100	-			57

TABLE A-1

INDUSTRIAL WASTE CHARACTERISTICS

DISTILLING INDUSTRY

Waste Source	Flow gpd	BOD_5 ppm	COD ppm	TOC ppm	SS ppm	TS ppm	Total N ppm	P as PO_4, ppm	pH	Miscellaneous	References
Mushroom	6,600*	463			145						-
Potatoes, White	-	200-2900			990-1,180						-
Potatoes, Sweet	3,500*	295			610						-
Potato Flour	-	7,420	12,582		6,862	11,792			4.2	V.S. = 10,614 ppm	-
Potato	129,000	1,340			3,950						49
Pineapple		100,000	176,000		950	152,000	370				49
Citrus Fruit	700,000	2,100			1,200					Settleable Solids = 100 mg/l	-
Potatoes - Lye Peeling		1,950	2,830		2,470	14,900			11.5		-
Lye Peeling			12,000			15,000			12-13		
Lye Peeling		2,550	3,505						12.4		-
Peas, Soft Fruit		700		350	194	1,437	37	18			23
Beans, Cauliflower		388		180	36	1,220	8	2			23
Beans, Leaf Veg.		77		96	41	488	5	1			23
Sprouts, Celery, Spin.		60		44	37	672	1	2			23
Celery, Peas, Sprouts		250		150	50	1,870	6	6			23

TABLE A-1

INDUSTRIAL WASTE CHARACTERISTICS

FRUIT AND VEGETABLE PROCESSING

*gal/Ton processed.

Waste Source	Flow MGD	BOD_5 mg/l	COD mg/l	T.D.S. mg/l	S.S. mg/l	NH_3 as N mg/l	Phenols mg/l	SO_4 mg/l	Cl mg/l	Oils mg/l	T.S. mg/l	References
Coke Ovens & By-Products Section	-	1,400	1,800	500		262	500	100	70			52
Total Steel Plant	1.6		896	1,235	184	107	82	623	145			52
Total Steel Plant	5.9				3,125							89
Total Steel Plant				1,117	1,649					121	2,766	101

TABLE A-1

INDUSTRIAL WASTE CHARACTERISTICS

IRON AND STEEL INDUSTRY

Source	Flow gal/ machine/day	BOD_5 mg/l	COD mg/l	PO_4 mg/l	ABS mg/l	pH	D.S. mg/l	S.S. mg/l	SO_4 mg/l	References
Launderette	-		447	148	44	-	812	173	200	85
Launderette	400		591	123	584	5.1	1,044	167		85
Launderette	400		403	190	31.8	7.6	699	216		85
Launderette	400		332	94	36.3	6.8	777	90		85
Launderette				250	40-80					
Launderette		243	572	264	63					
Launderette		221			51			98		98
Launderette		61			30			28		98
Launderette		162			38			100		111
Launderette		132			35			220		111
Launderette			367		70.5			151		31
Launderette	400		650	150	50	7	800	150	195	31
			Mean 480	Mean 174	Mean 47			Mean 139		

TABLE A-1

INDUSTRIAL WASTE CHARACTERISTICS

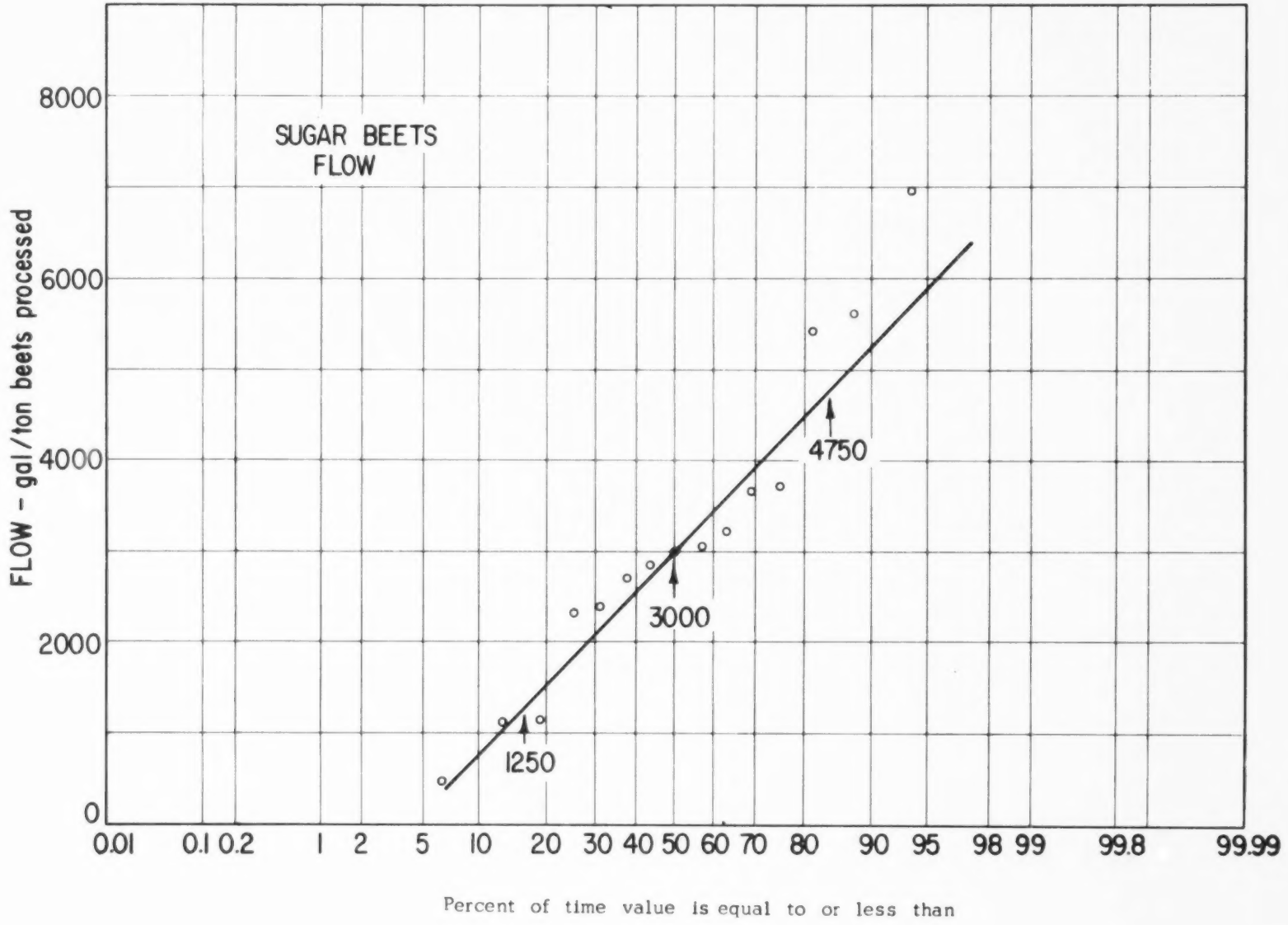
LAUNDERETTES

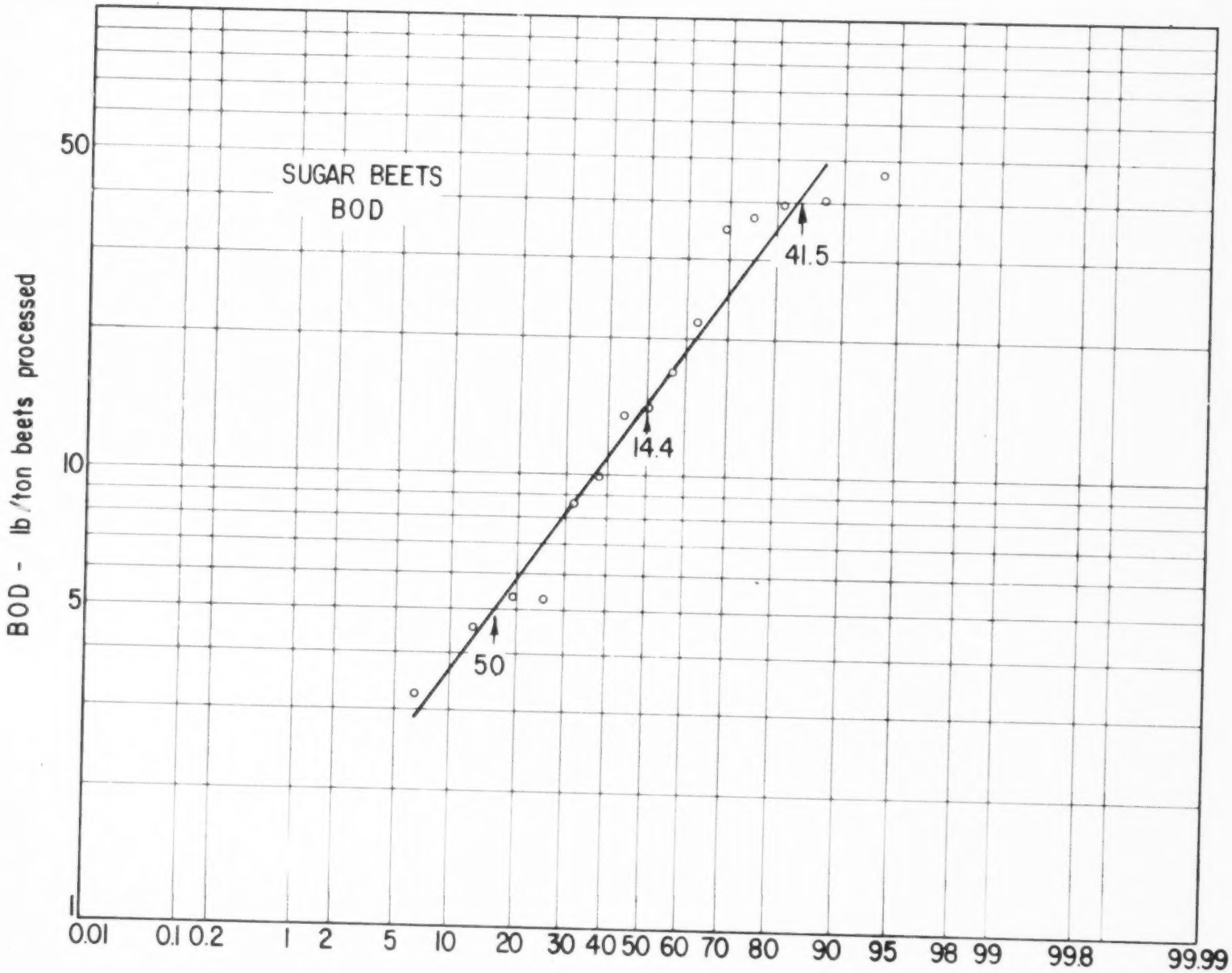
Waste Source	Flow MGD	BOD_5 ppm	COD ppm	Total N ppm	P as PO_4 ppm	Phenols	Oils ppm	S.S. ppm	T.S. ppm	Cl^- ppm	$S^=$ ppm		References
Total Refinery	780	54	212	21 (NH_3)	6.5					730			26
Total Refinery	0.43	1,600	1,600			56	90						48
Total Refinery		145				23	450				11.8		-
Total Refinery	0.289	1,600	1,200-2,350			40-80							-
Total Refinery	781	70	284	25 (NH_3)	1	2.8	50				12.7		-
Total Refinery	210		426	51 (NH_3)		12.6					8.8		-
Total Refinery	-		1,300	14.3(NH_3)		2.2	110			106	0		92
Total Refinery	-		528	14.3(NH_3)		0.2	43				0		92
Total Refinery	-		752	23 (NH_3)		0.6	93			134	0		92
Total Refinery	1,407		8,832	3,197 (NH_3)		212.9					2,216		-
Total Refinery	3.73	190	534	21	2	36	61	289	6,730	6,440		Sulfur = 19 ppm	Private Communications
Total Refinery	2.448	345	1,350	89	2	160	73	200	3,771	2,060	128	SO_4 = 280 ppm	Private Communications
Total Refinery	12	227	976	54 (NH_3)	2.5			270	2,385				Private Communications
Total Refinery	1.76		384			8.5					15		7
Total Refinery	1.69		287			55					2		7
Total Refinery	5.85		280			15							7
Total Refinery	0.092		2,020			237					40		7
Refinery + Domestic	0.2	122				15					0.25		7

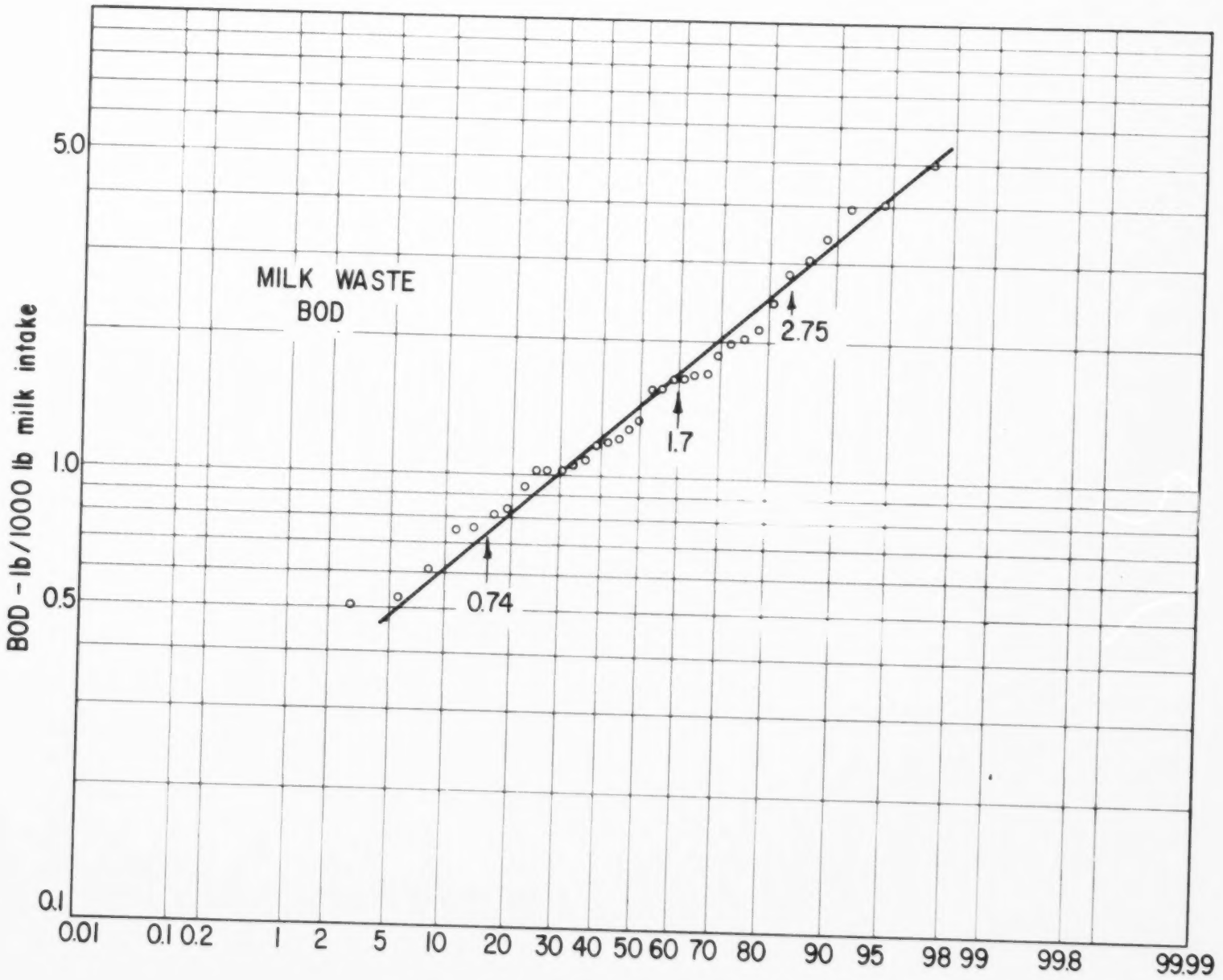
TABLE A-1
INDUSTRIAL WASTE CHARACTERISTICS
PETROLEUM INDUSTRY

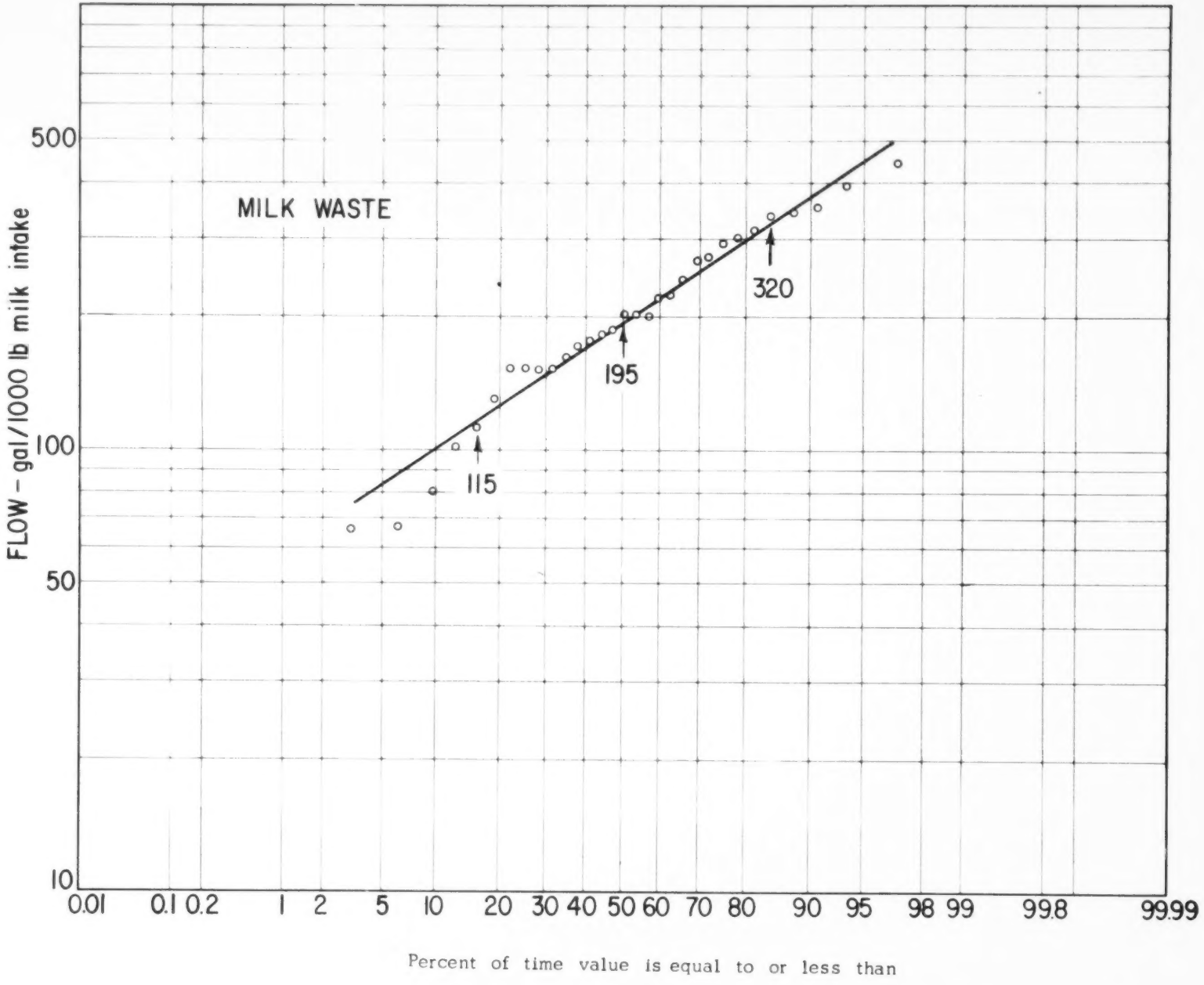
Waste Source	Flow MGD	BOD_5 ppm	COD ppm	Total N ppm	P as PO_4 ppm	Phenols	Oils ppm	S_2O_3 ppm	T_2S_2 ppm	Cl^- ppm	$S^=$ ppm		References
Total Refinery	1.01	111				11.4	20					Temp = 88°F	7
Total Refinery	0.22	200	250			12	50					Temp = 95°F	7
Total Refinery	0.77		272			85						Temp = 82°F	7
Total Refinery	1.76		157			0.7						Temp = 94°F	7
Total Refinery	0.304		1,000			190						Temp = 110°F	7
Total Refinery	0.07					125						Temp = 98°F	7
-	0.058		4,000			800					300		7
-	0.044					600					200		7
Total Refinery	1.72	109				2							7
Total Refinery	0.29		700			30	50						7
Total Refinery	1.16	109	314	32 (NH_3)		5.7	76				7.2		93
-	-	175	467	20 (NH_3)		7.4	197				8		93
Total Refinery	2.45	345	855								150		93
Total Refinery	3.74	190	534			36	61					Temp = 74°F	93
Total Refinery	15.0	227	976									Temp = 90°F	93
Total Refinery	2.6	45	300										93
Total Refinery	10.5		977										93
Total Refinery	4.7		380										93
Total Refinery	26.65	70											93
Total Refinery	3.89	1,600	1,775			60							76

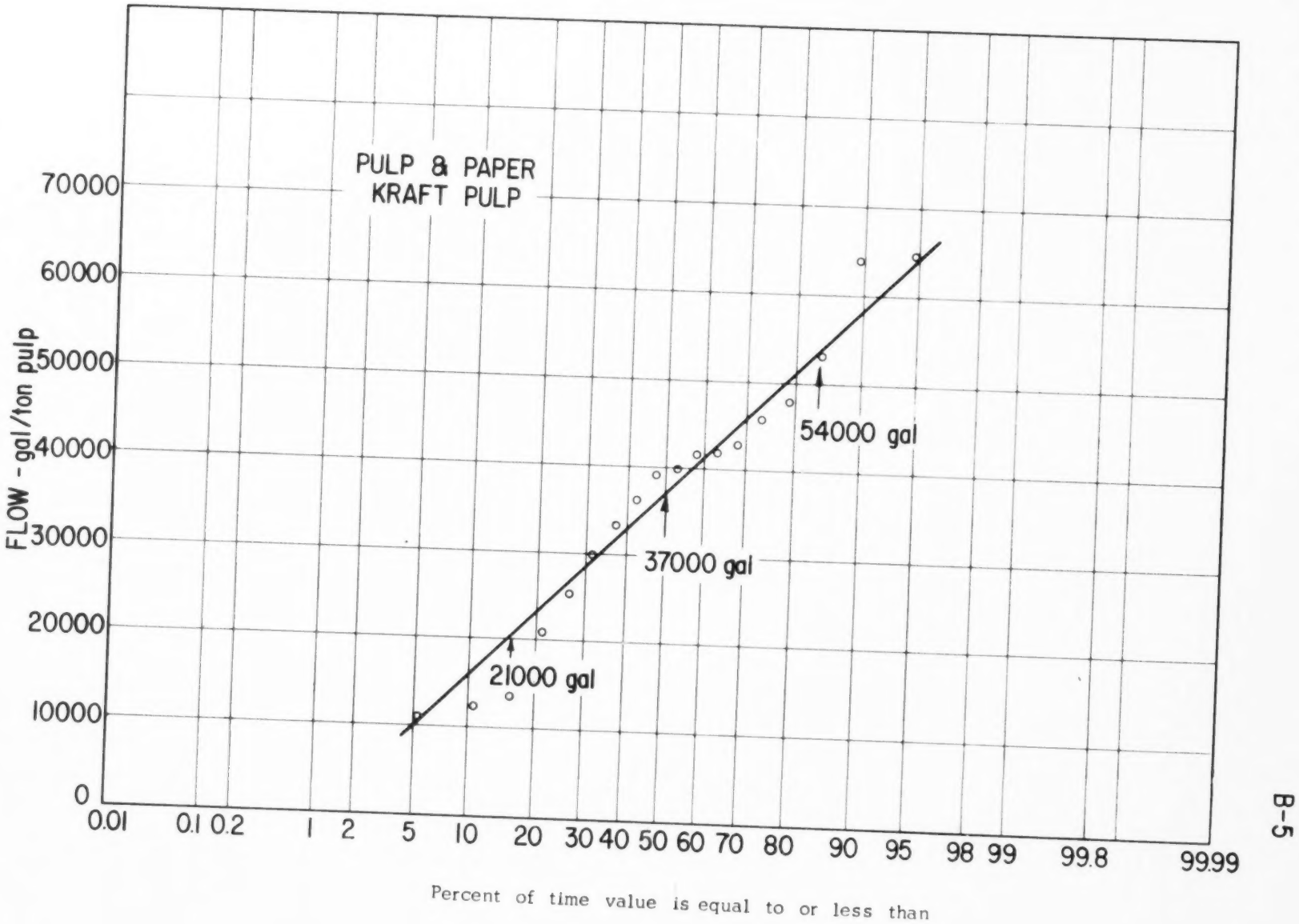
TABLE A-1
INDUSTRIAL WASTE CHARACTERISTICS
PETROLEUM INDUSTRY

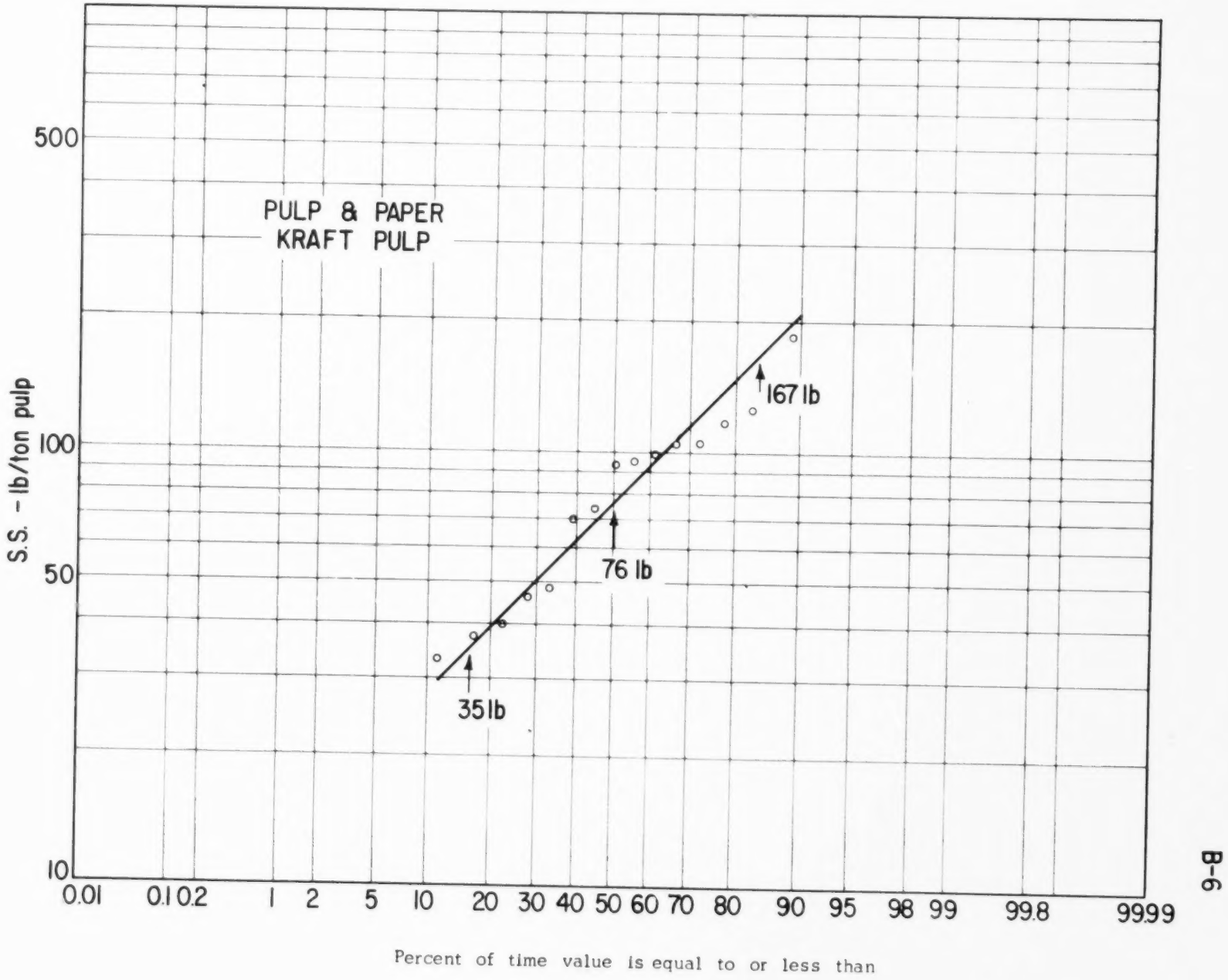

SUGAR BEETS
FLOW
FLOW - gal/ton beets processed
8000
6000
4000
2000
0
1250
3000
4750
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.99
Percent of time value is equal to or less than

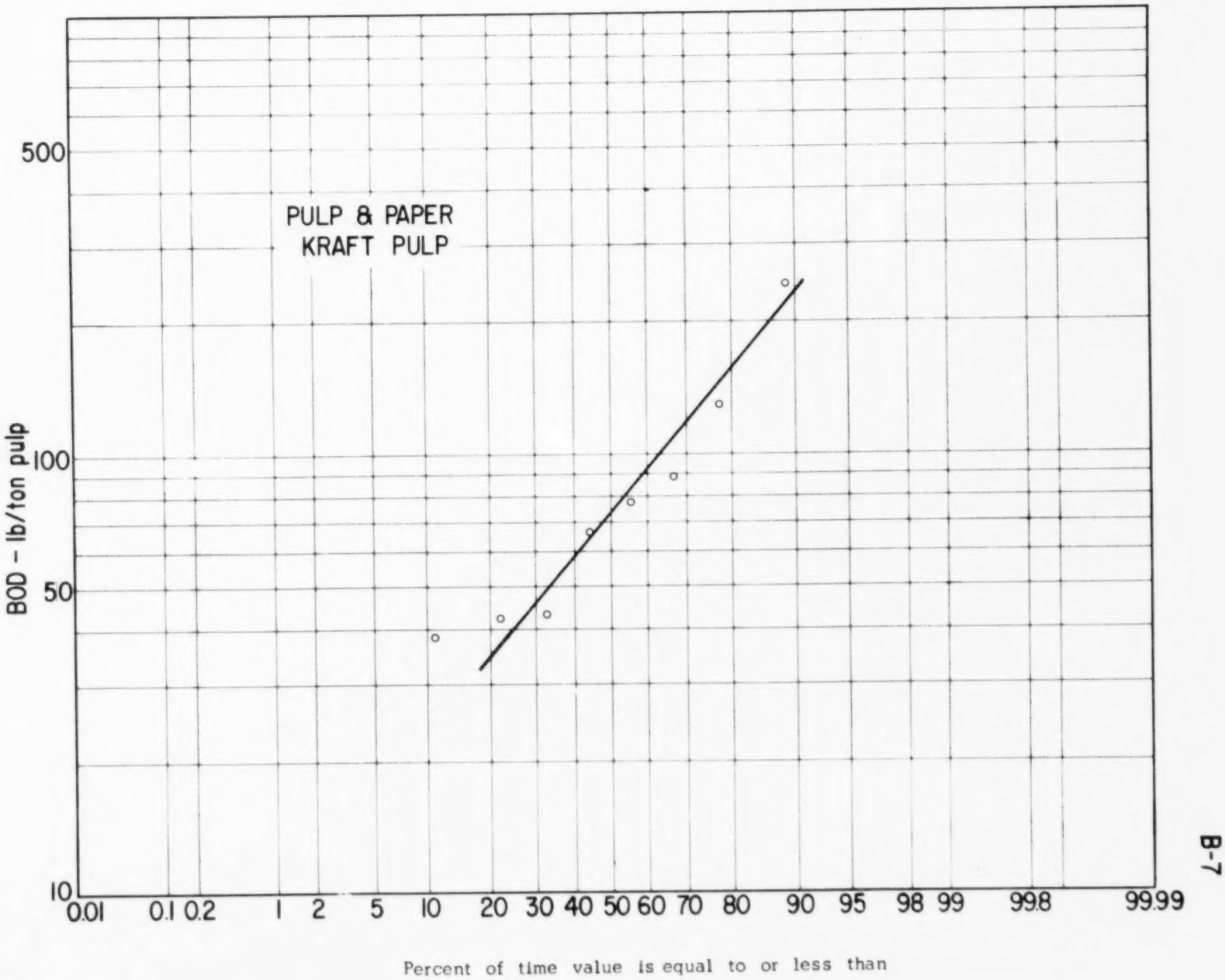

SUGAR BEETS
BOD
41.5
14.4
50
BOD - lb/ton beets processed
50
10
5
1
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

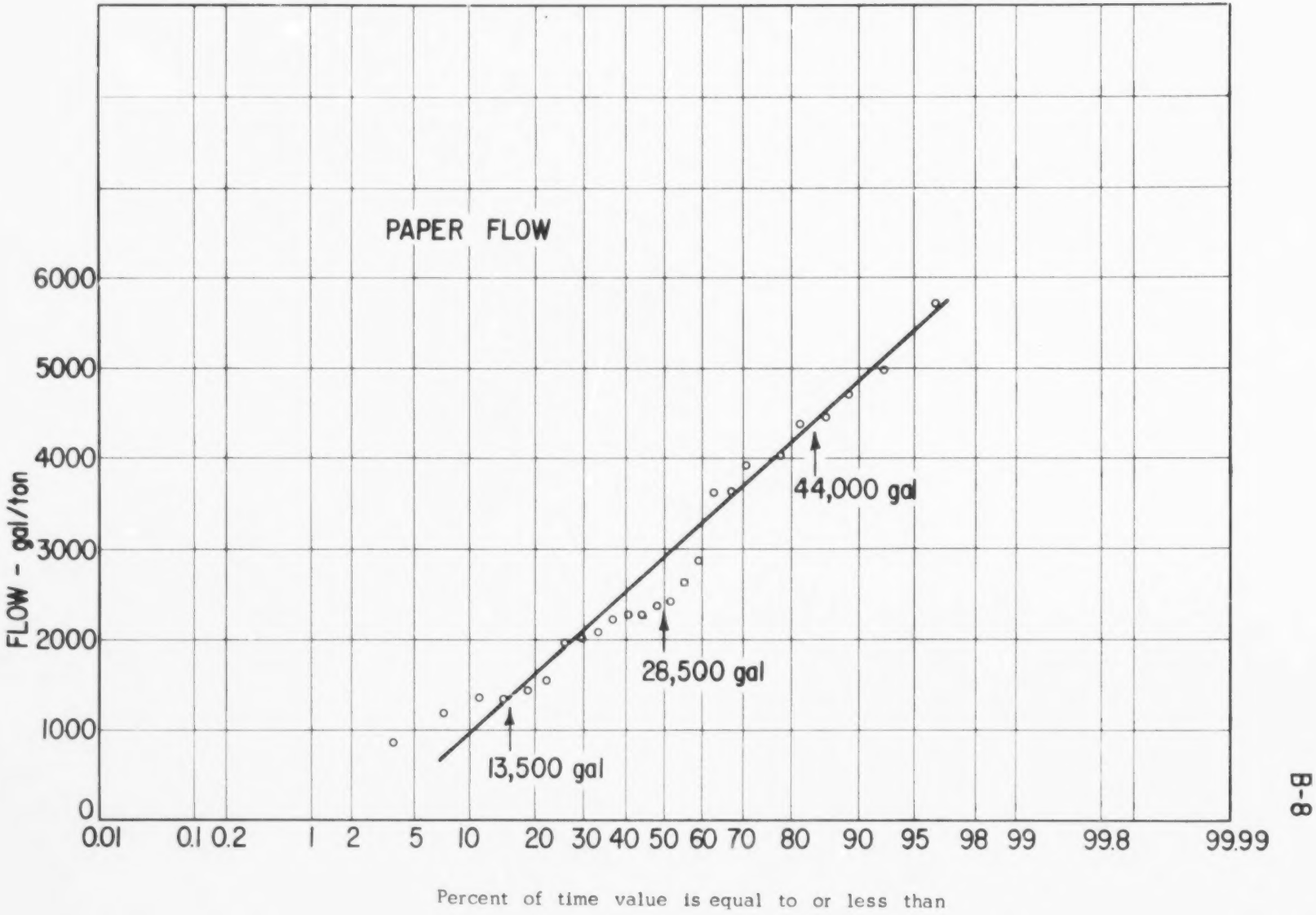

MILK WASTE
BOD
BOD - lb/1000 lb milk intake
5.0
1.0
0.5
0.1
0.74
1.7
2.75
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

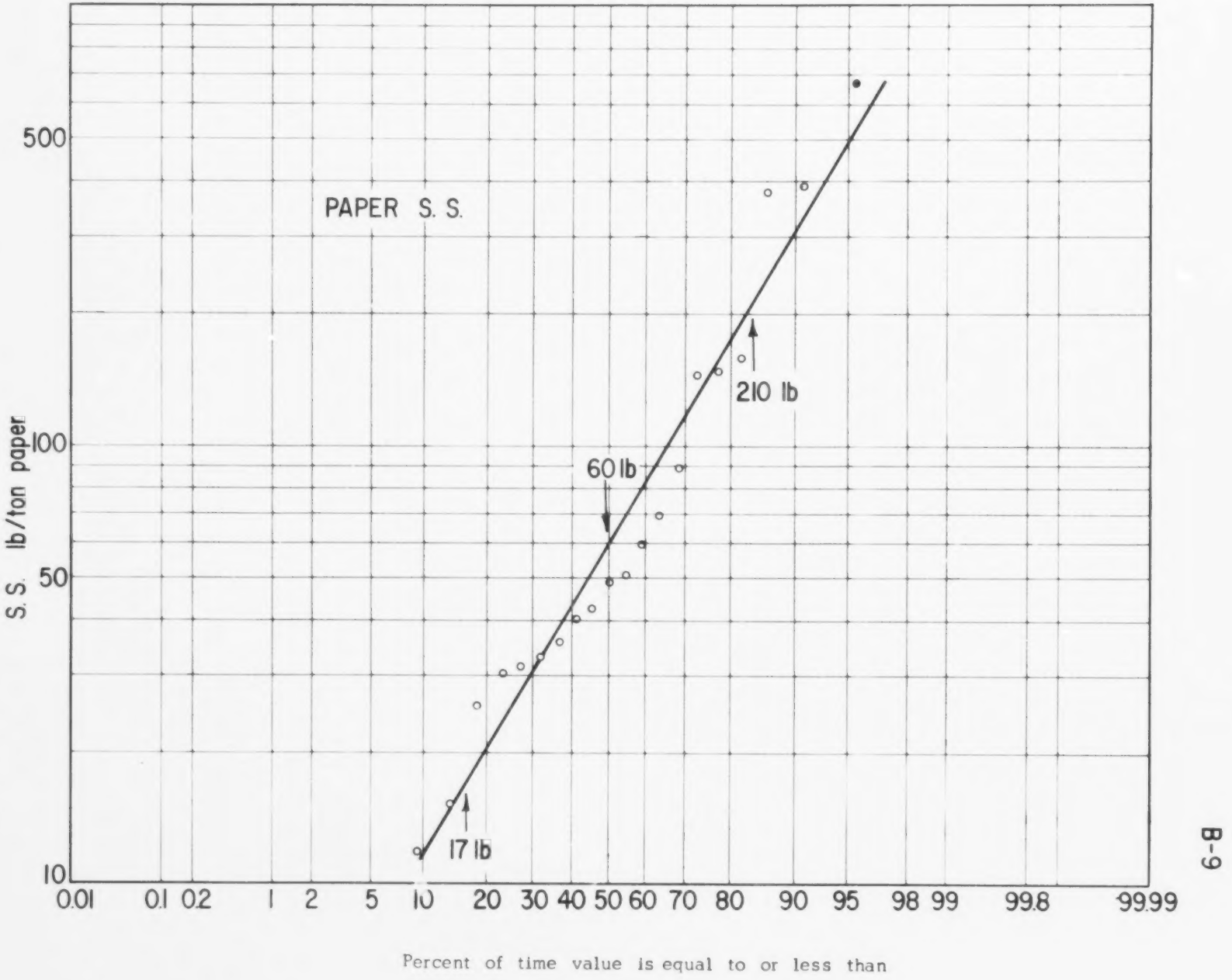

MILK WASTE
FLOW - gal/1000 lb milk intake
500
100
50
10
115
195
320
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

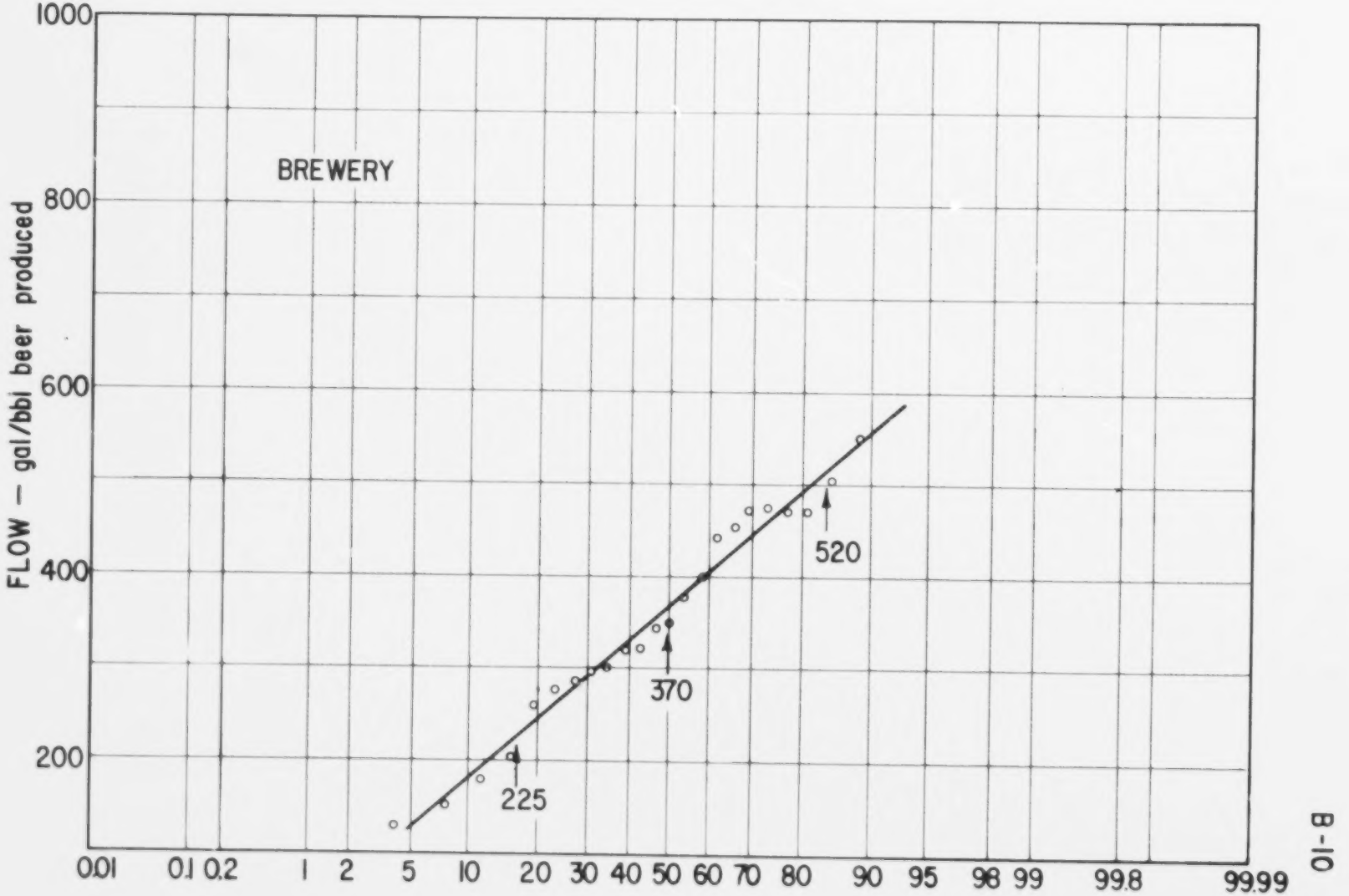

PULP & PAPER
KRAFT PULP
FLOW - gal/ton pulp
70000
60000
50000
40000
30000
20000
10000
0
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
21000 gal
37000 gal
54000 gal
Percent of time value is equal to or less than

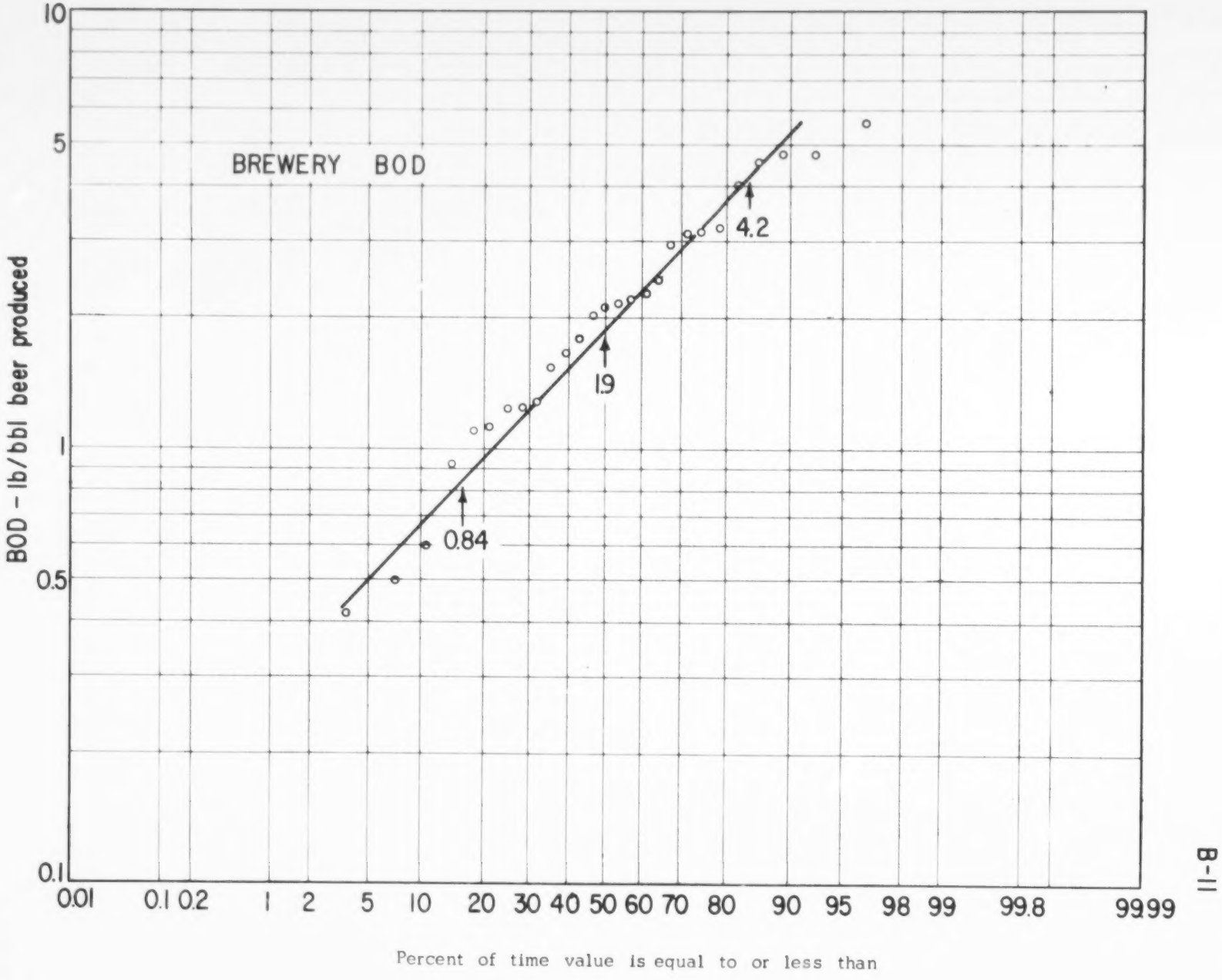

PULP & PAPER
KRAFT PULP
S.S. - lb/ton pulp
500
100
50
10
167 lb
76 lb
35 lb
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
Percent of time value is equal to or less than

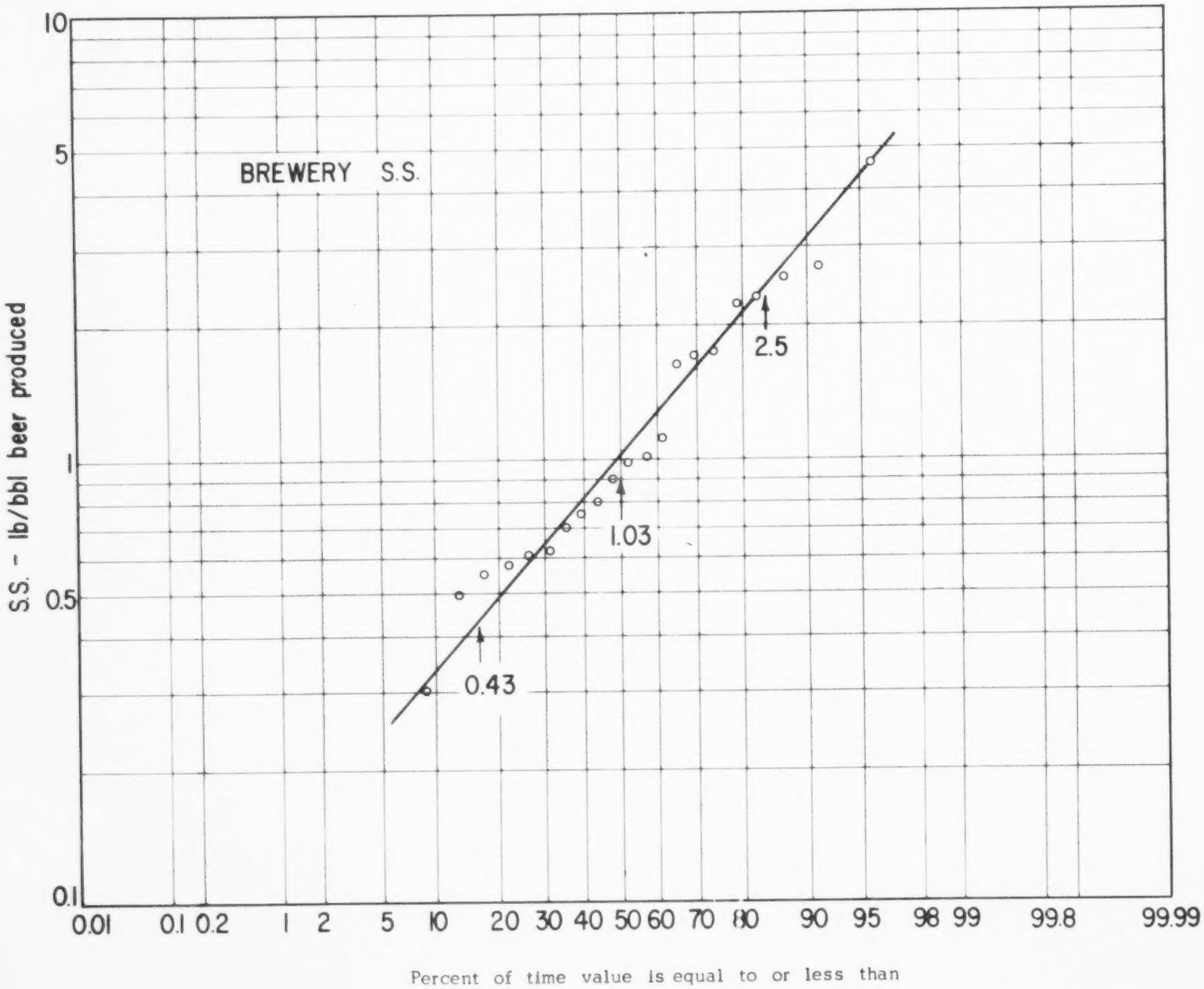

PULP & PAPER
KRAFT PULP
BOD - lb/ton pulp
500
100
50
10
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

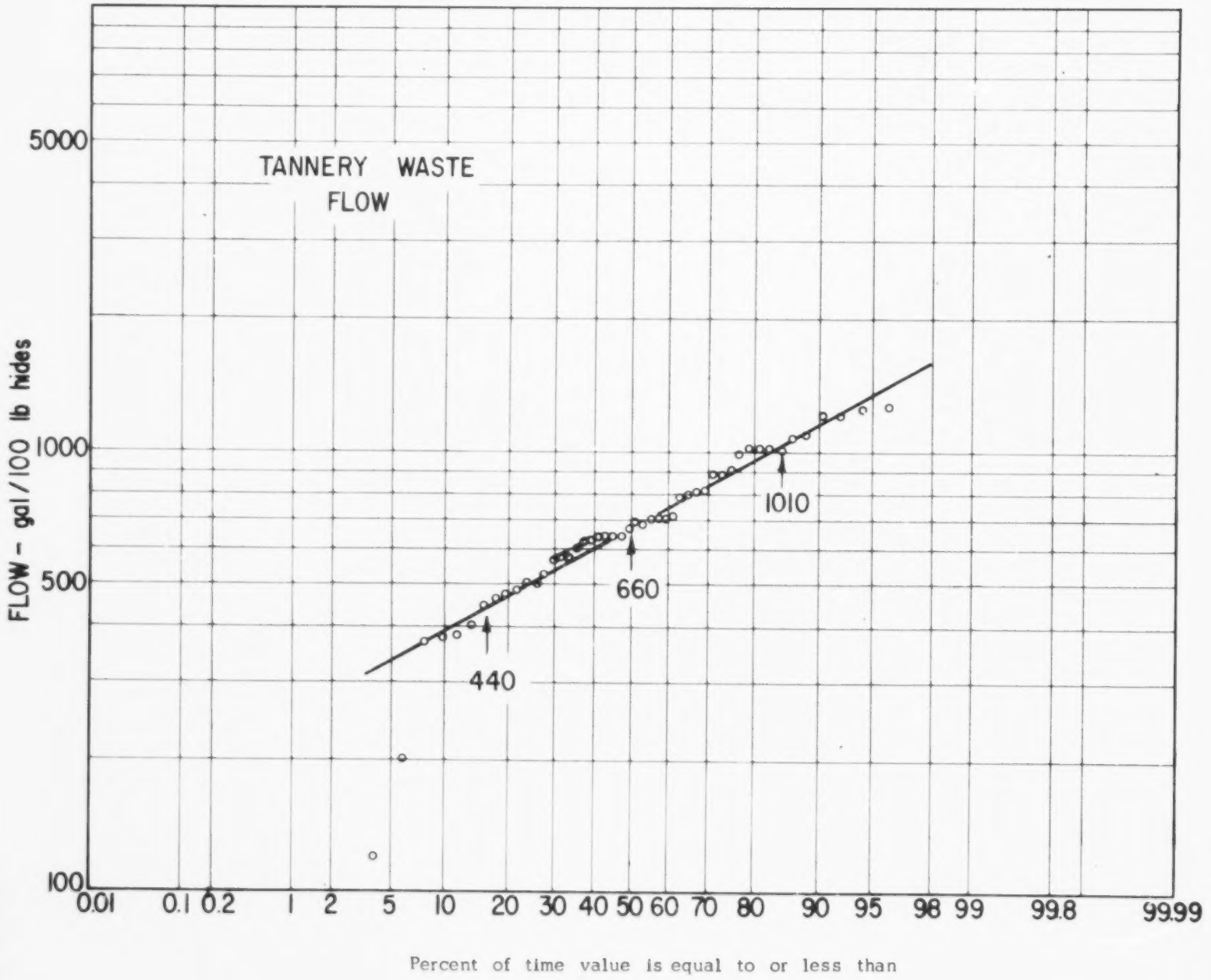

PAPER FLOW
FLOW - gal/ton
6000
5000
4000
3000
2000
1000
0
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
13,500 gal
28,500 gal
44,000 gal
Percent of time value is equal to or less than

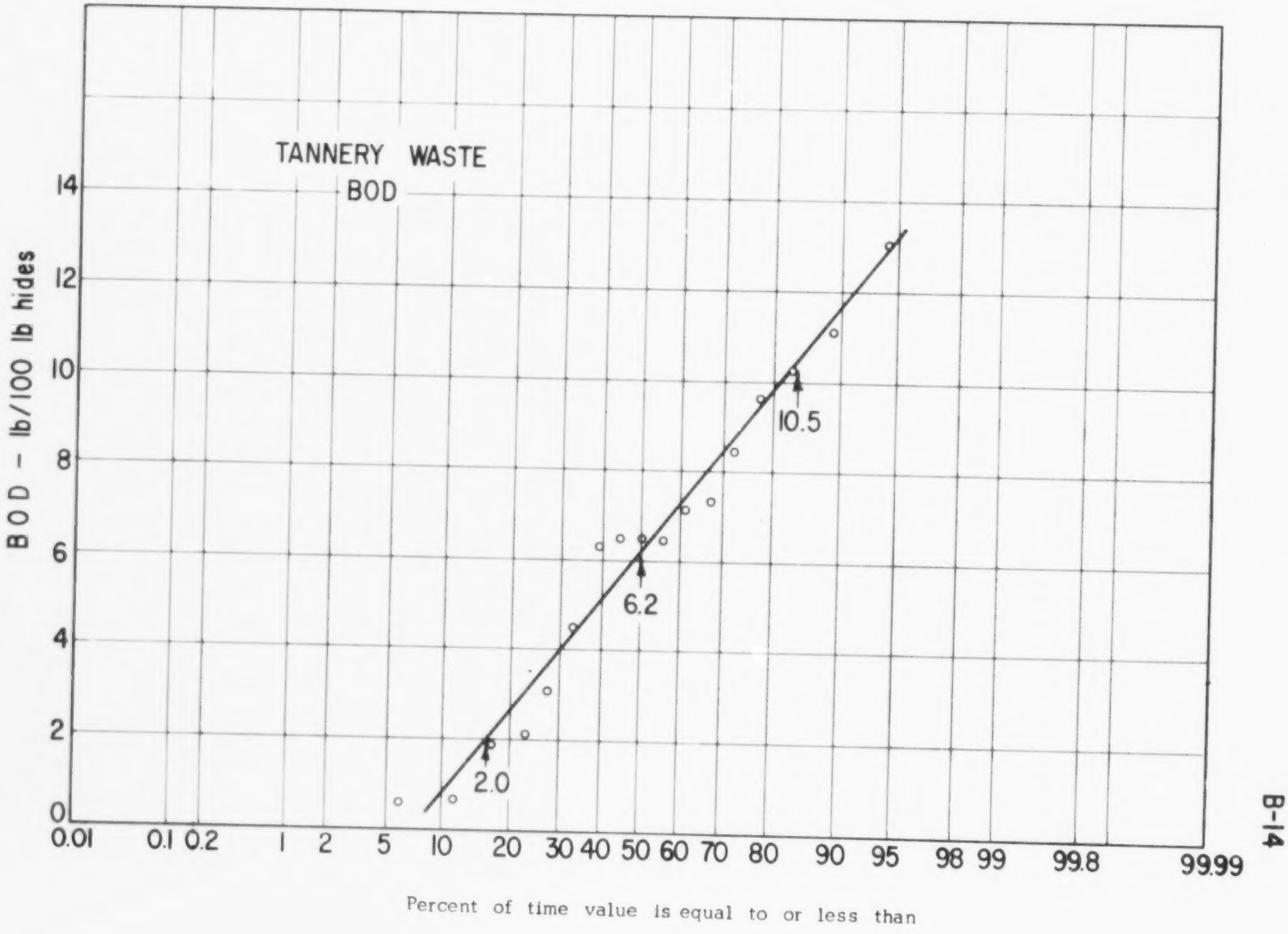

PAPER S. S.
S. S. lb/ton paper
500
100
50
10
17 lb
60 lb
210 lb
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

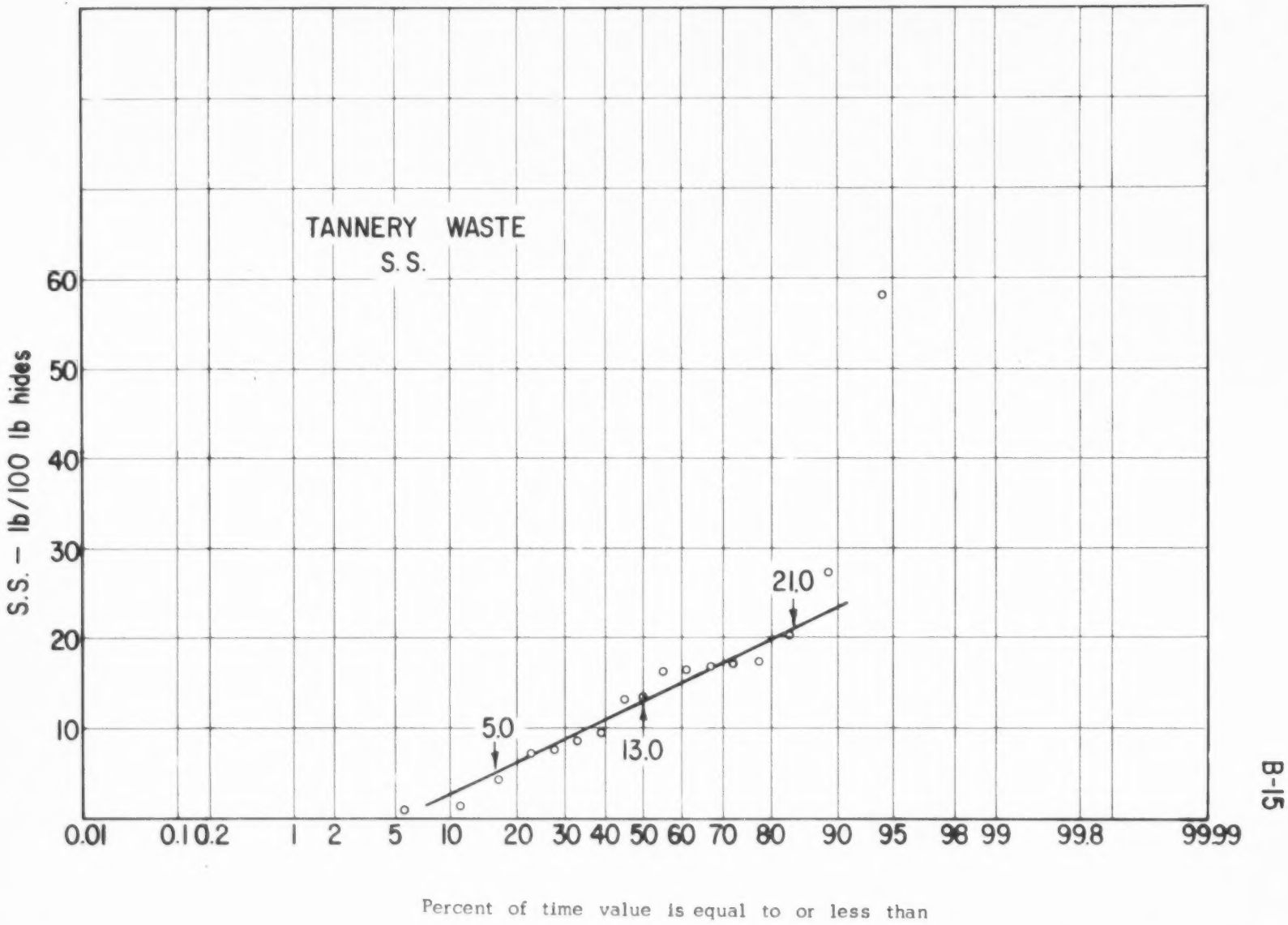

BREWERY
FLOW — gal/bbl beer produced
1000
800
600
400
200
225
370
520
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

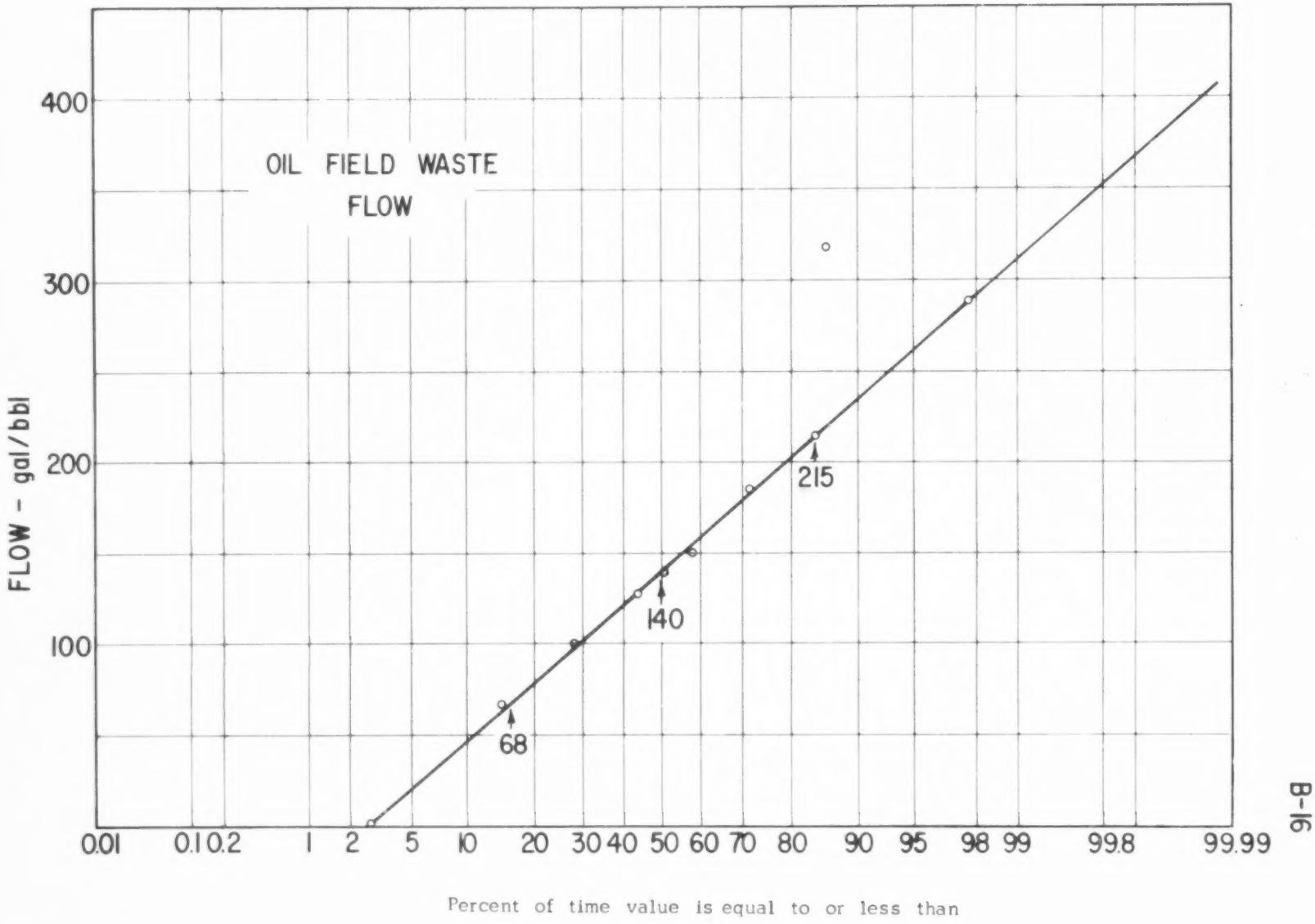

BREWERY BOD
BOD - lb/bbl beer produced
10
5
1
0.5
0.1
0.84
1.9
4.2
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

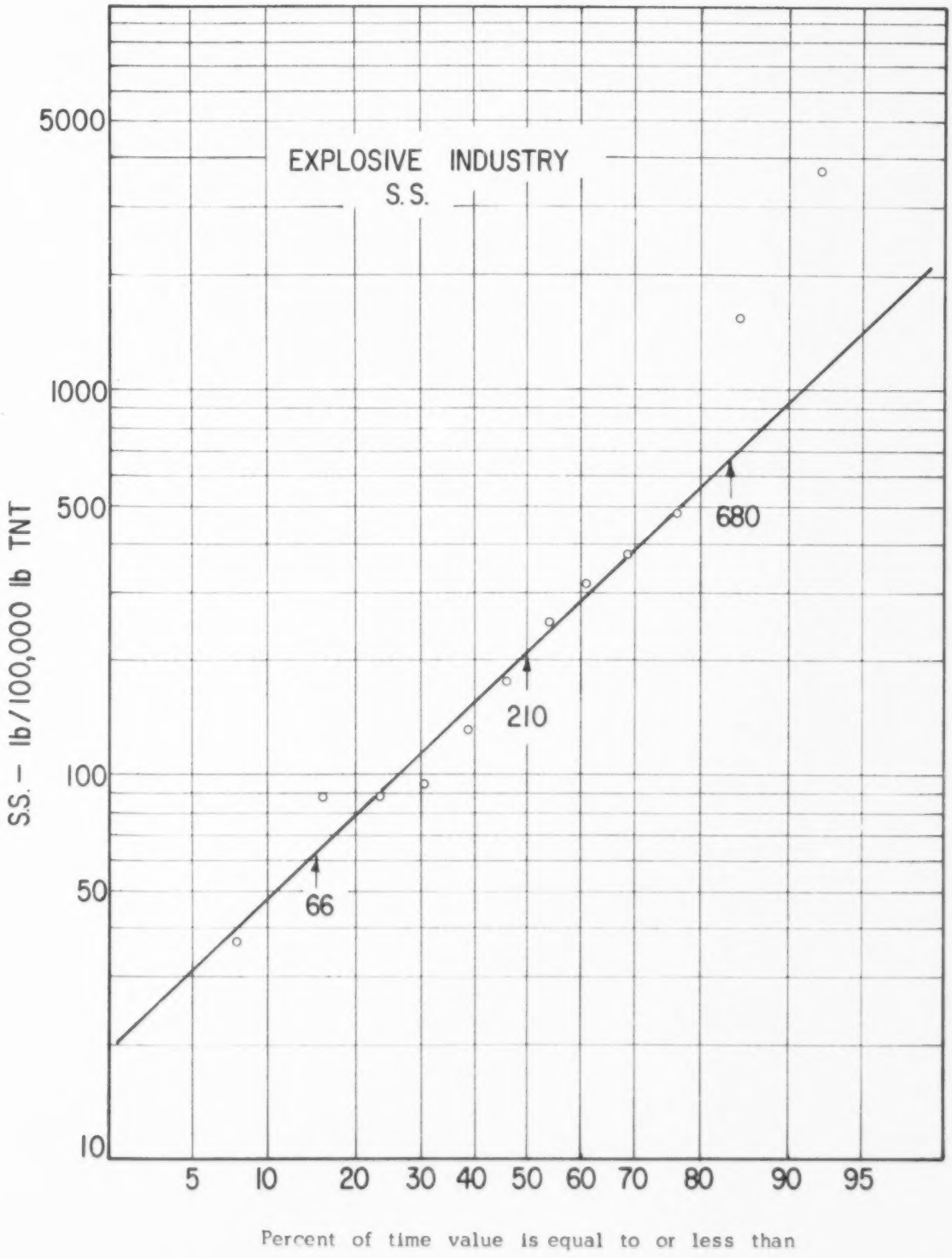

BREWERY S.S.
S.S. - lb/bbl beer produced
10
5
1
0.5
0.1
0.43
1.03
2.5
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.99
Percent of time value is equal to or less than

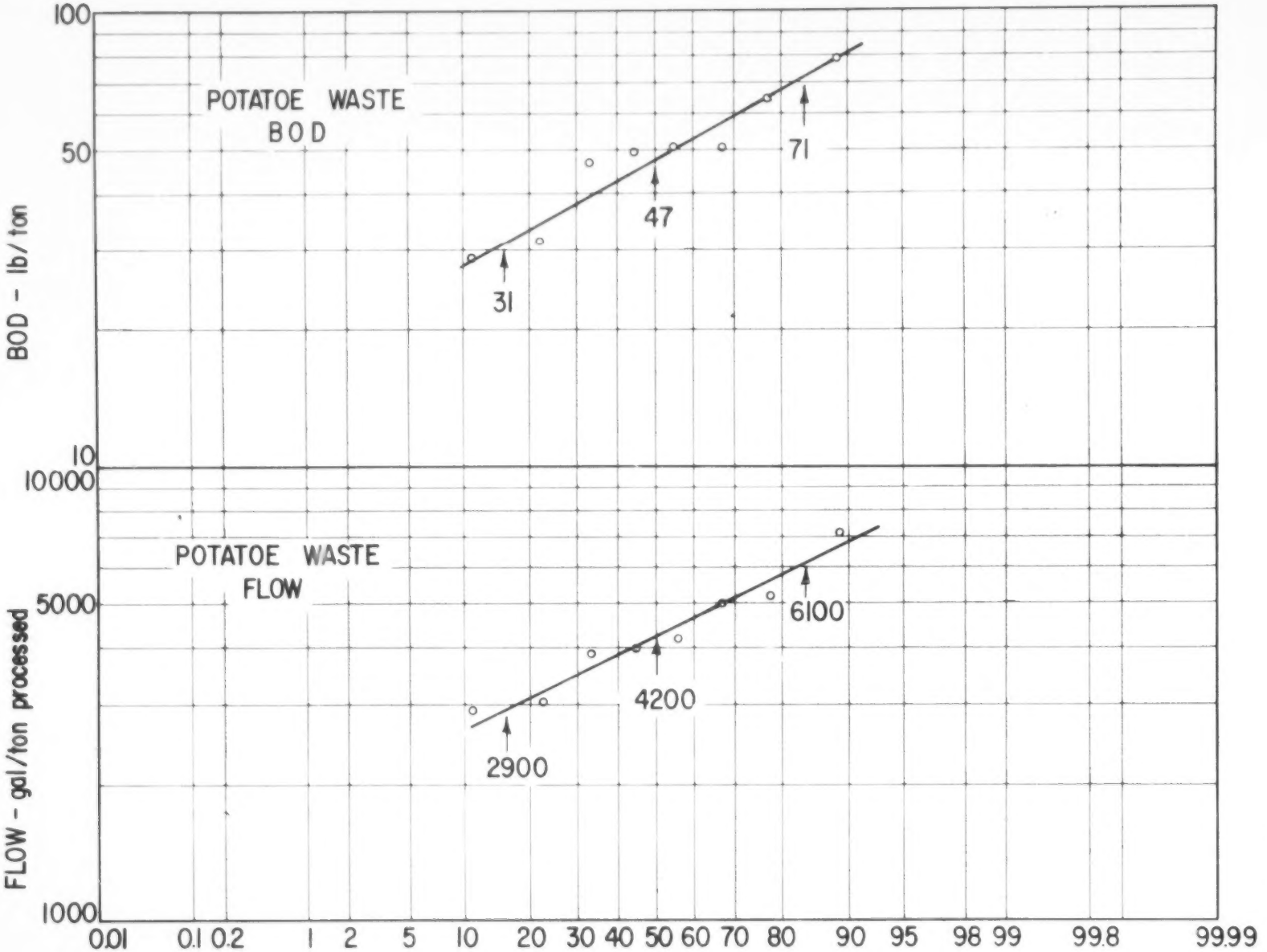

TANNERY WASTE
FLOW
FLOW - gal/100 lb hides
5000
1000
500
100
440
660
1010
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

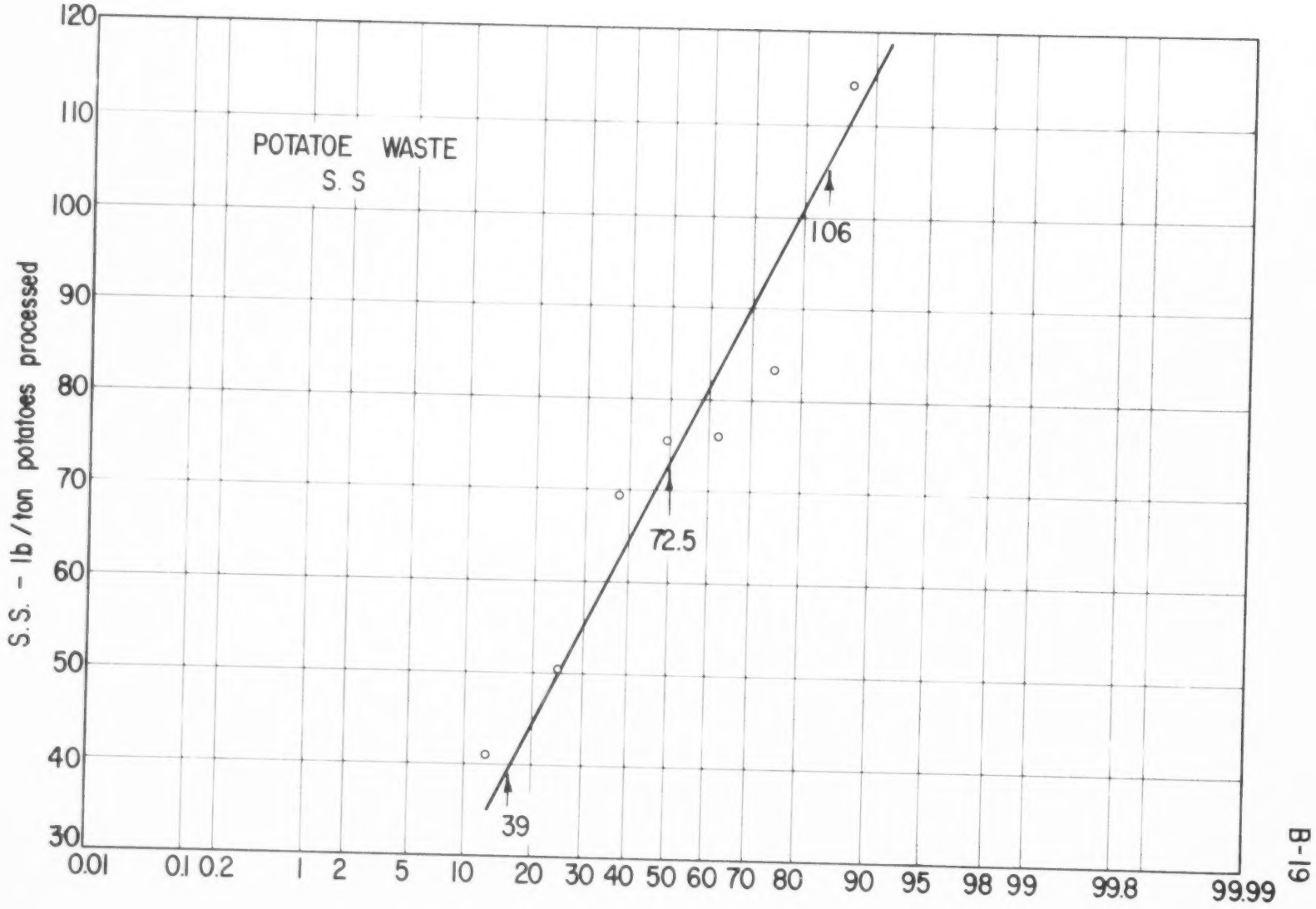

TANNERY WASTE
BOD
BOD - lb/100 lb hides
0
2
4
6
8
10
12
14
2.0
6.2
10.5
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

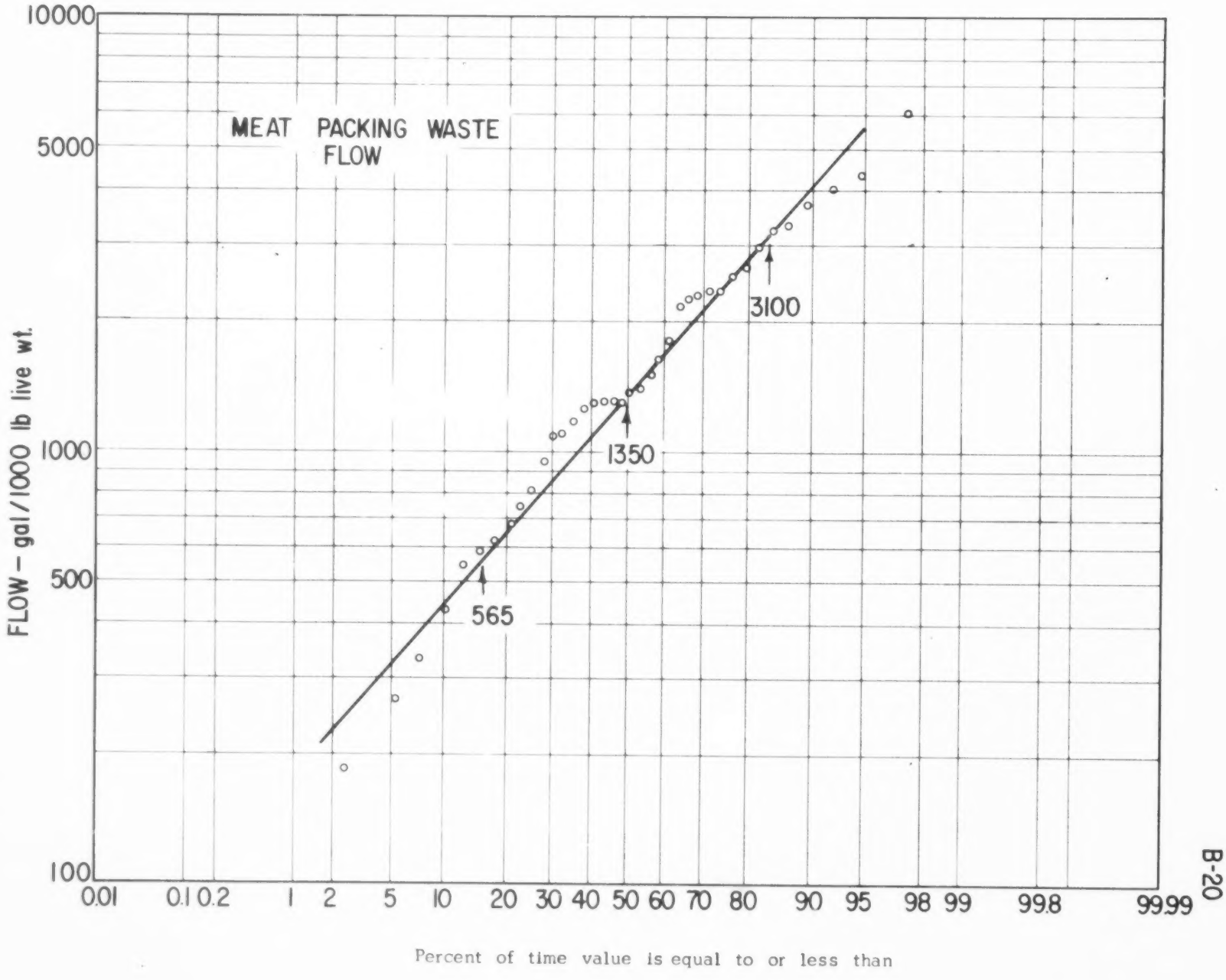

TANNERY WASTE
S. S.
S.S. – lb/100 lb hides
60
50
40
30
20
10
21.0
5.0
13.0
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

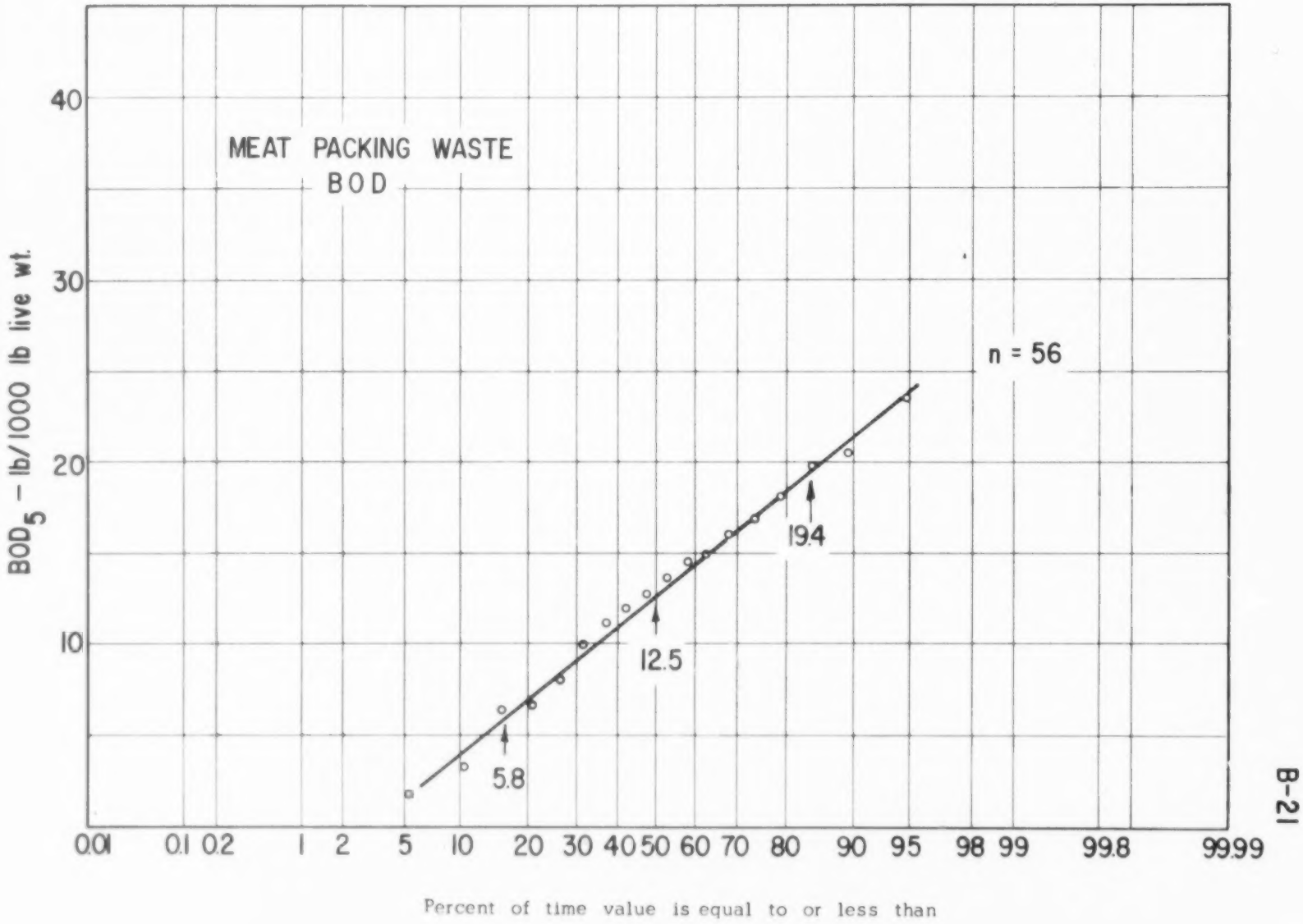

OIL FIELD WASTE
FLOW
FLOW - gal/bbl
400
300
200
100
68
140
215
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

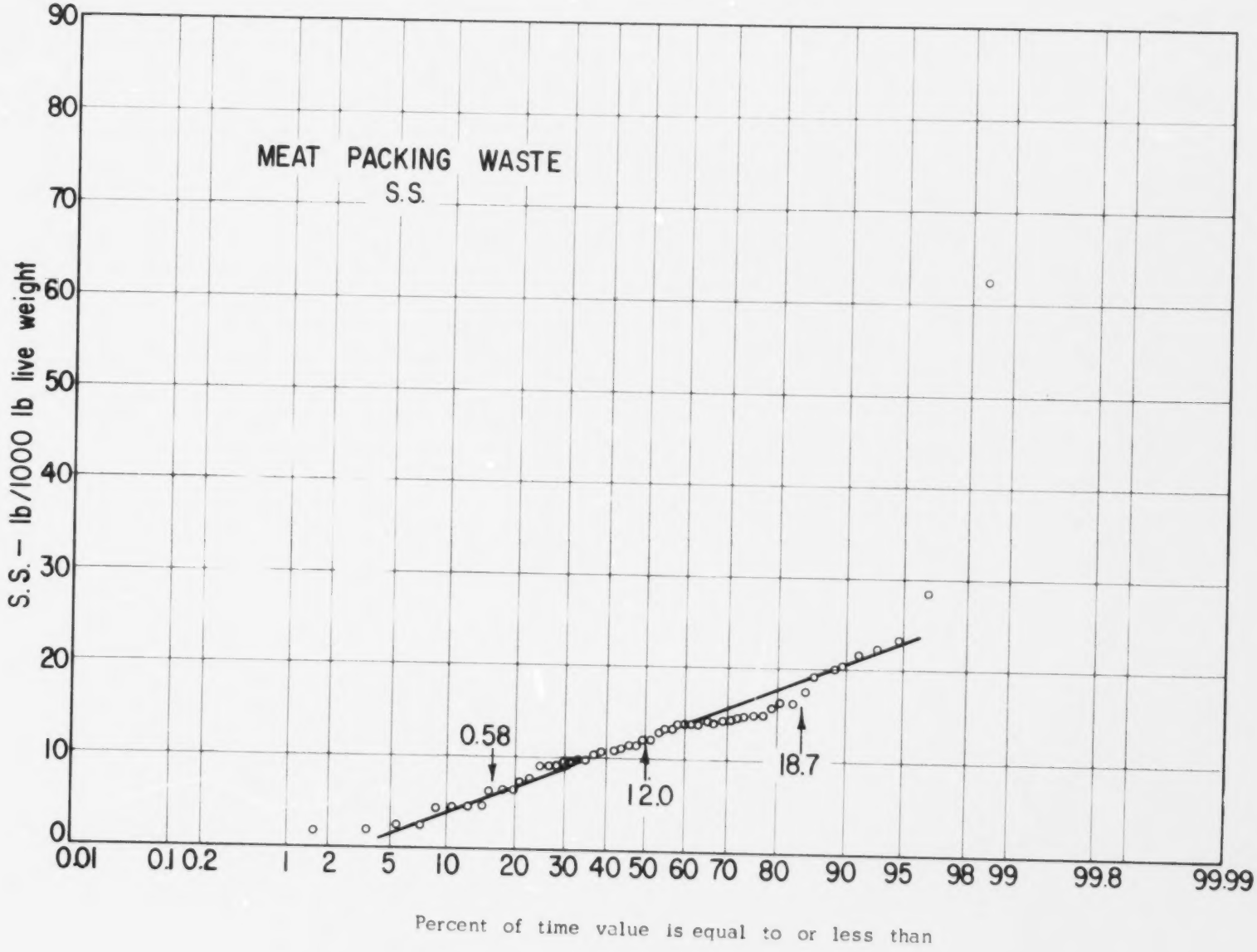

EXPLOSIVE INDUSTRY
S.S.
5000
1000
500
100
50
10
680
210
66
S.S. - lb/100,000 lb TNT
5
10
20
30
40
50
60
70
80
90
95
Percent of time value is equal to or less than

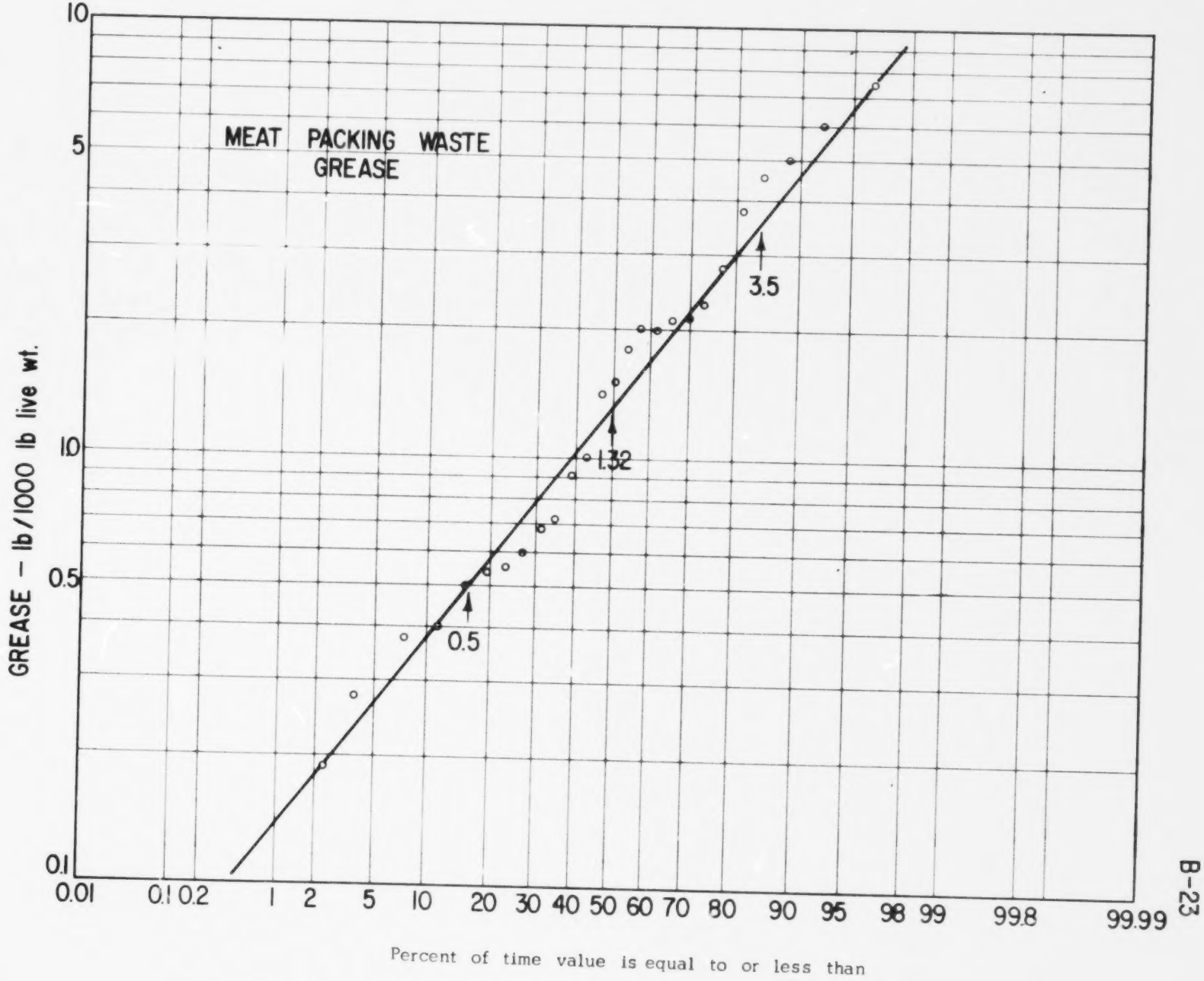

POTATOE WASTE
BOD
BOD - lb/ton
100
50
10
31
47
71
POTATOE WASTE
FLOW
FLOW - gal/ton processed
10000
5000
1000
2900
4200
6100
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

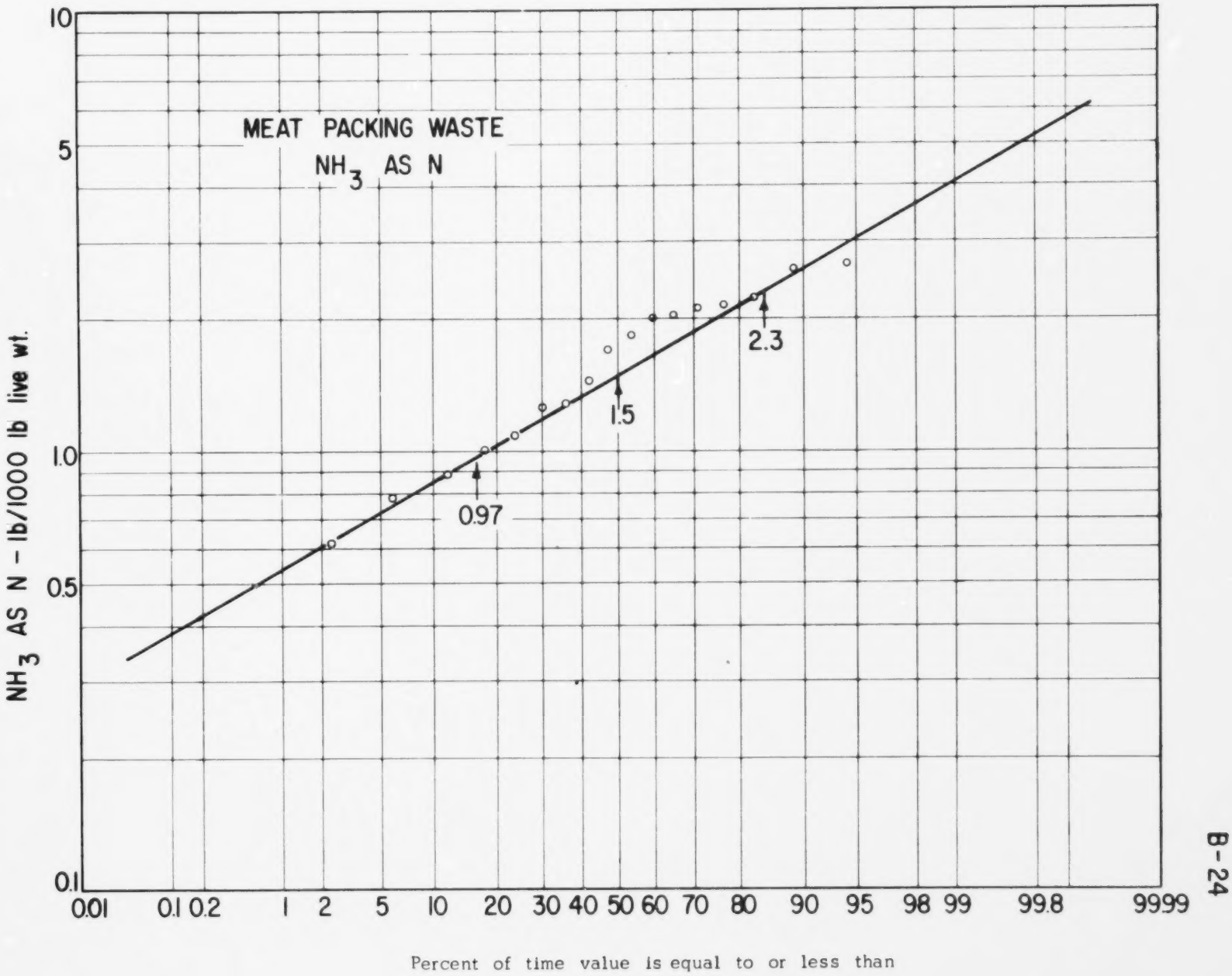

POTATOE WASTE
S. S
S.S. - lb / ton potatoes processed
120
110
100
90
80
70
60
50
40
30
106
72.5
39
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

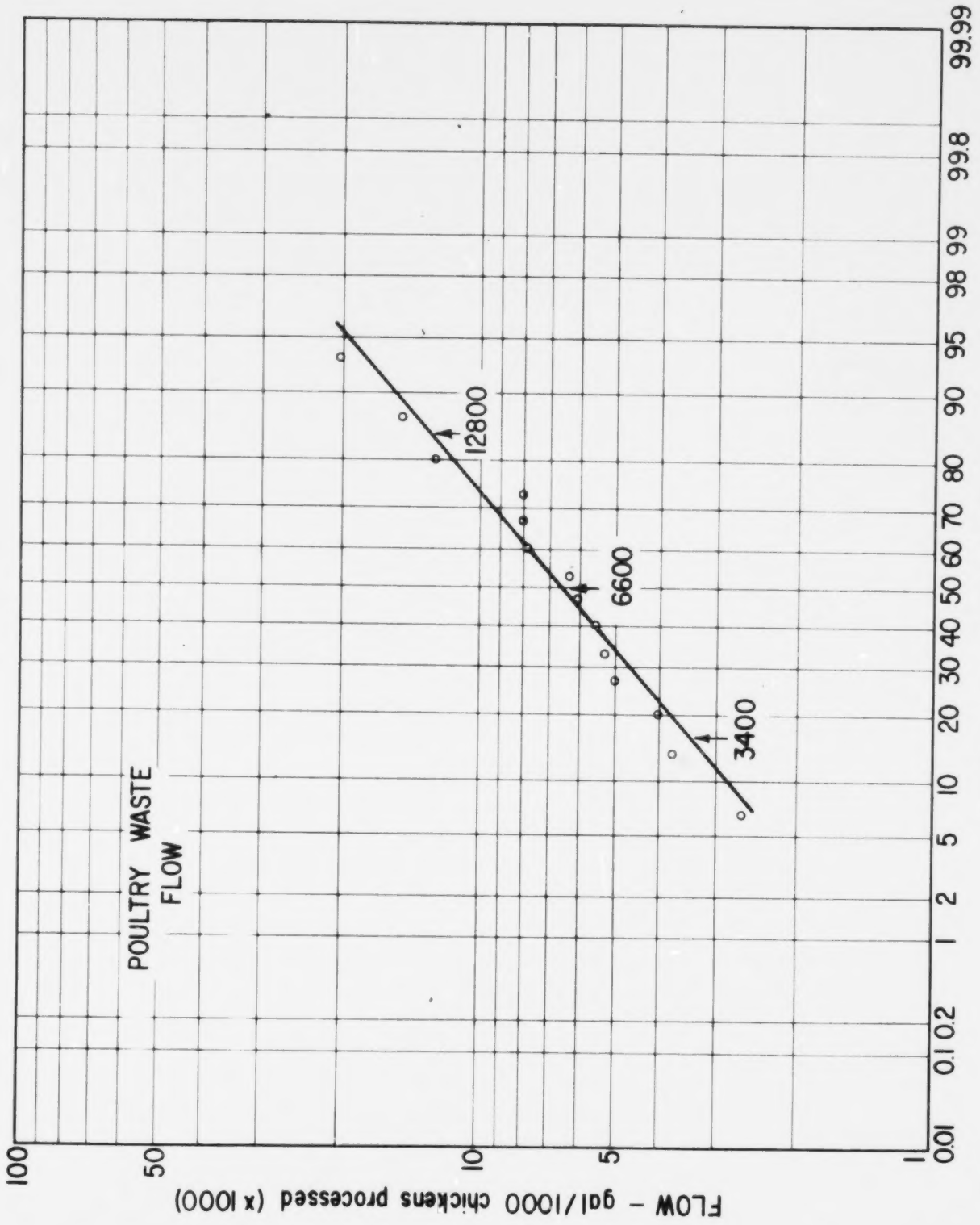

MEAT PACKING WASTE
FLOW
10000
5000
1000
500
100
FLOW – gal/1000 lb live wt.
565
1350
3100
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

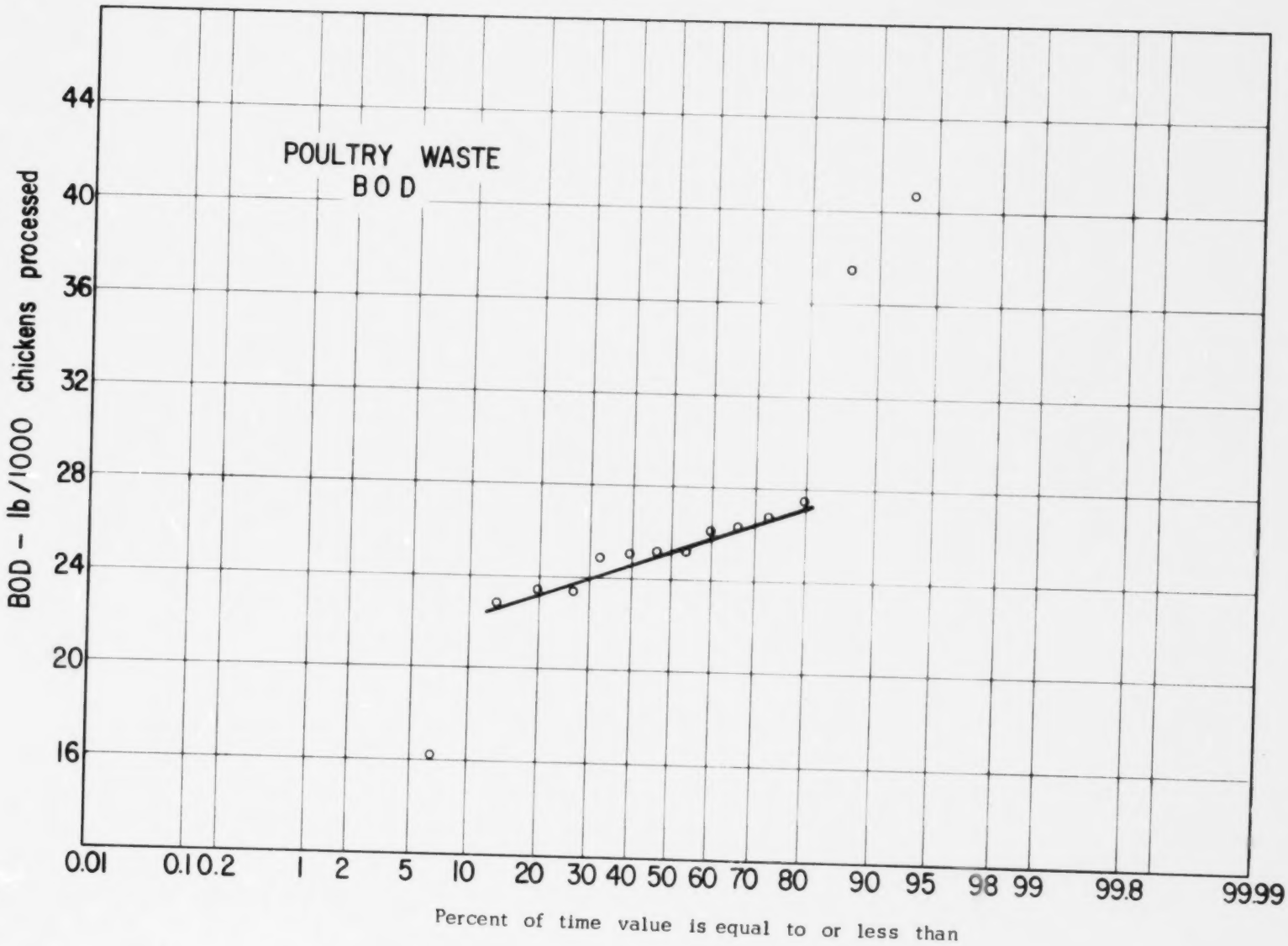

MEAT PACKING WASTE
BOD
n = 56
5.8
12.5
19.4
40
30
20
10
BOD5 – lb/1000 lb live wt.
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.99
Percent of time value is equal to or less than

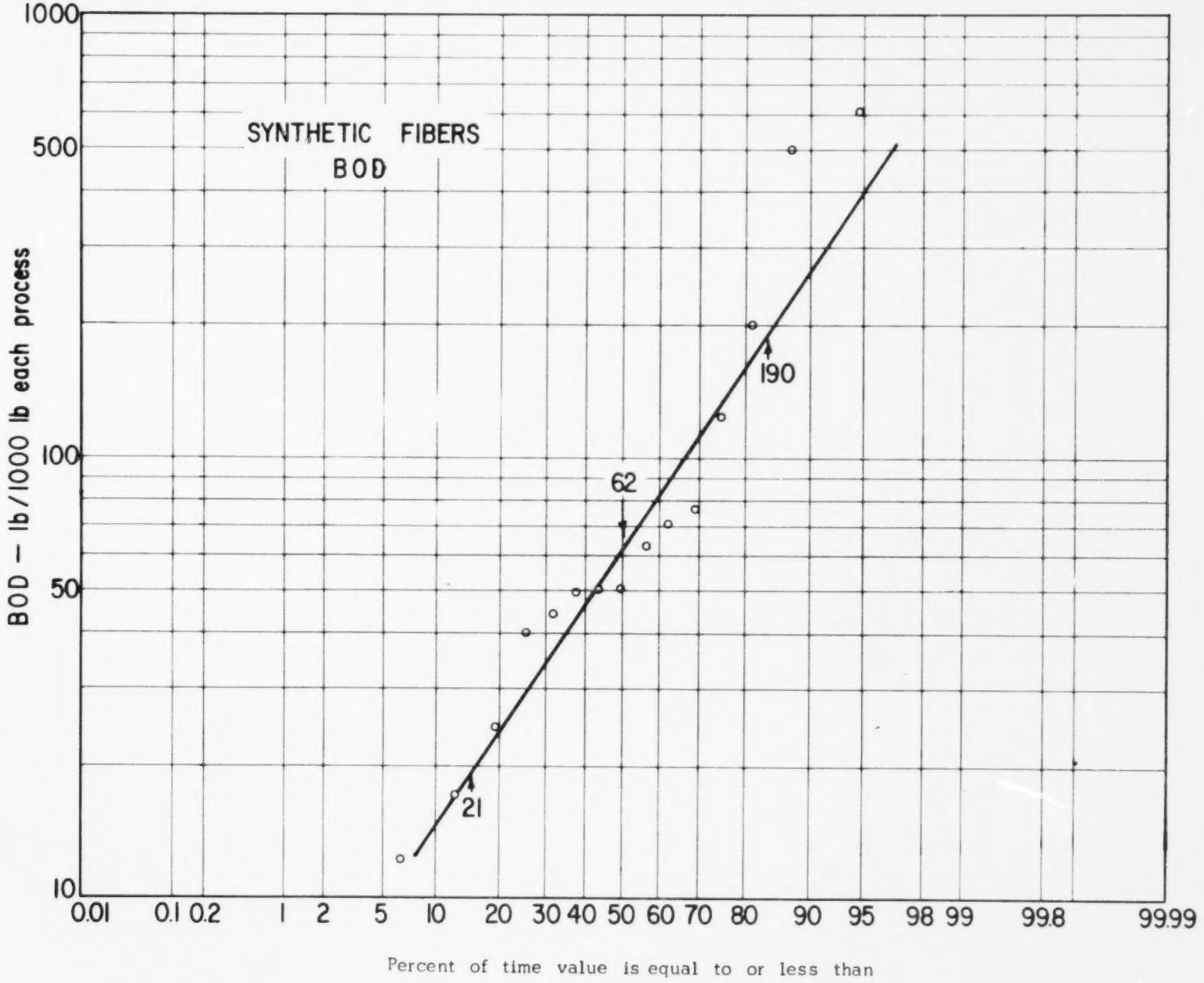

MEAT PACKING WASTE
S.S.
S.S. – lb/1000 lb live weight
90
80
70
60
50
40
30
20
10
0
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
0.58
12.0
18.7
Percent of time value is equal to or less than

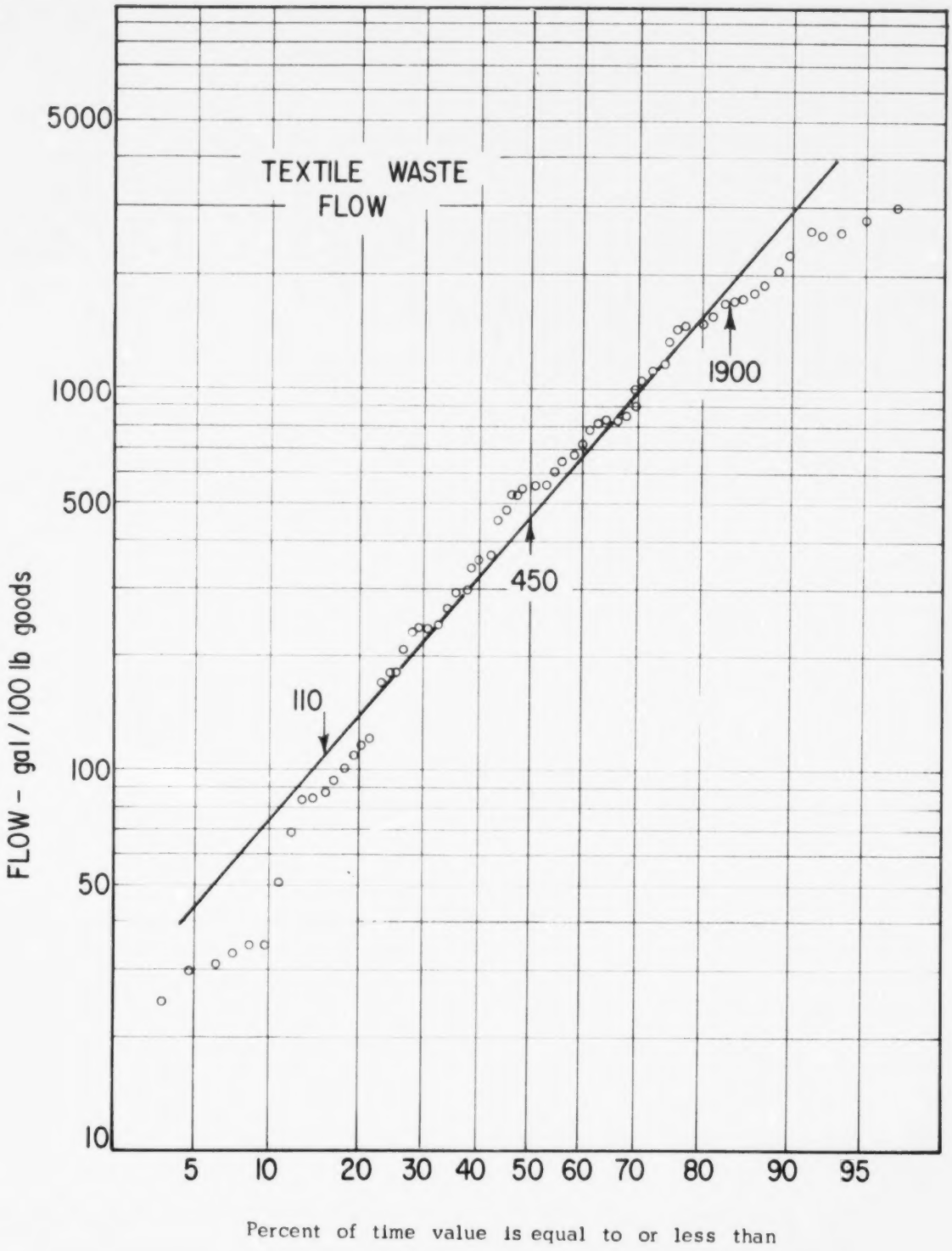

MEAT PACKING WASTE
GREASE
GREASE – lb/1000 lb live wt.
10
5
1.0
0.5
0.1
0.5
1.32
3.5
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

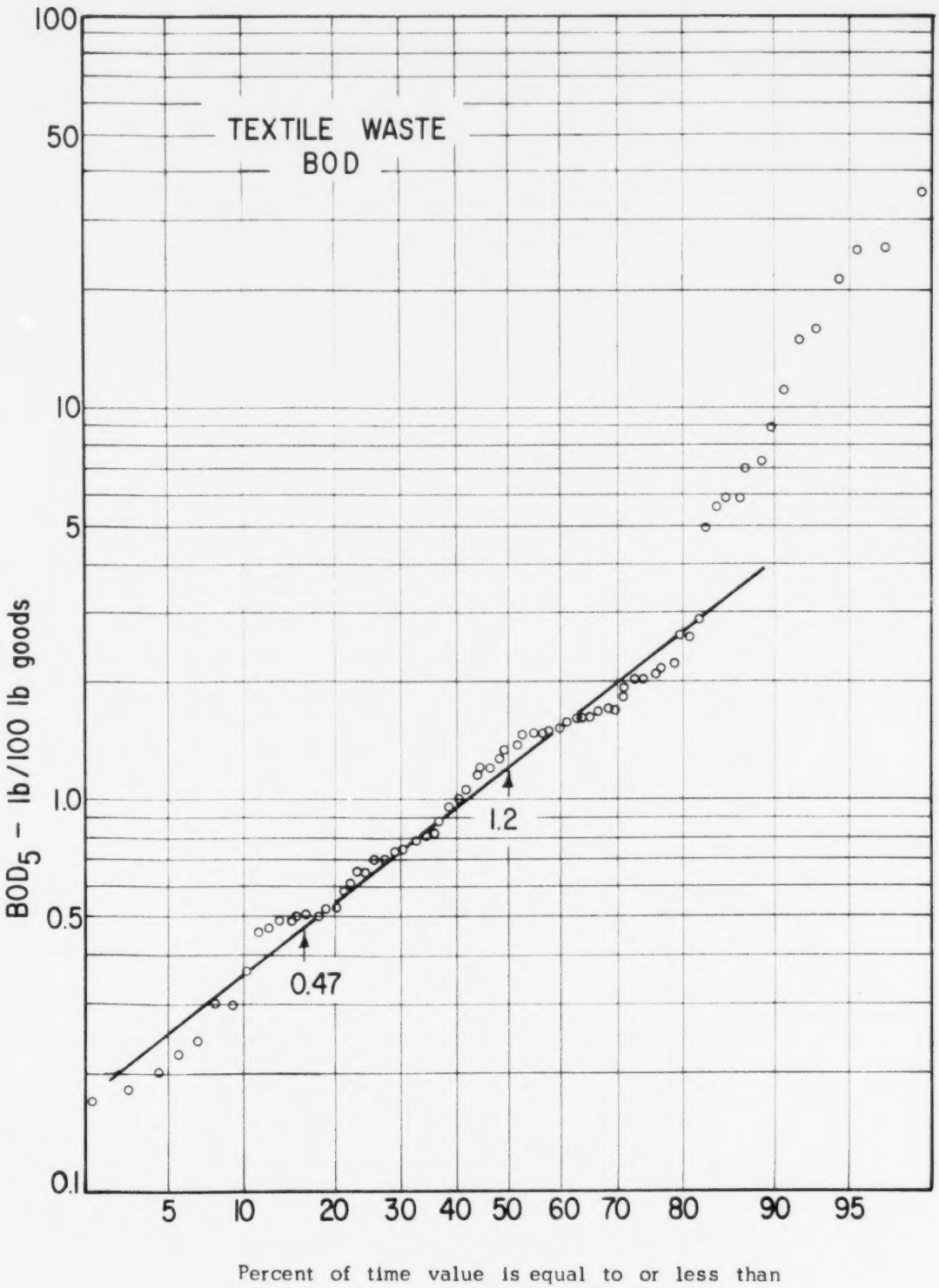

MEAT PACKING WASTE
NH3 AS N
NH3 AS N - lb/1000 lb live wt.
10
5
1.0
0.5
0.1
0.97
1.5
2.3
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.99
Percent of time value is equal to or less than

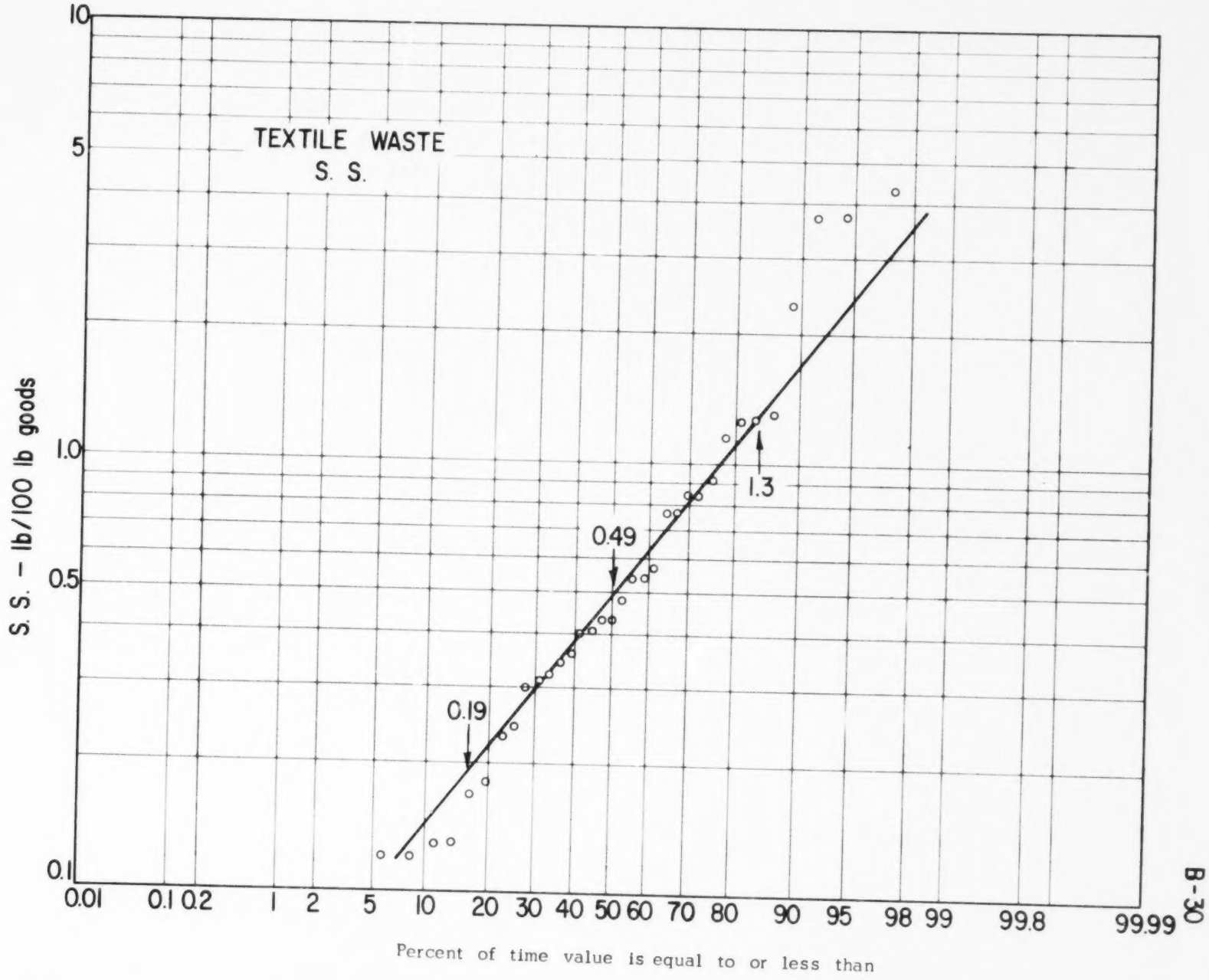

POULTRY WASTE FLOW
FLOW – gal/1000 chickens processed (x1000)
100
50
10
5
1
12800
6600
3400
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.99
Percent of time value is equal to or less than

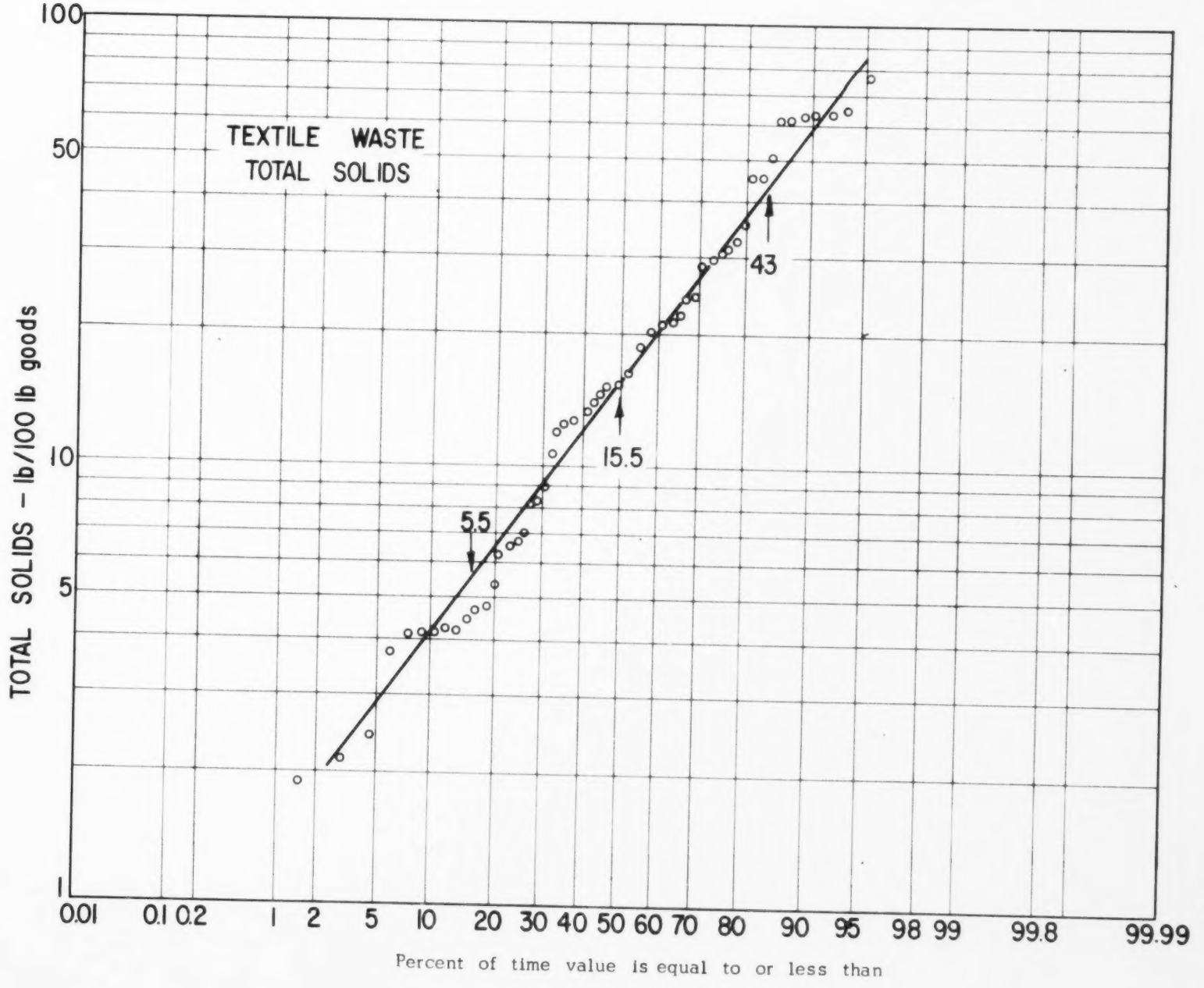

POULTRY WASTE
BOD
BOD - lb/1000 chickens processed
44
40
36
32
28
24
20
16
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

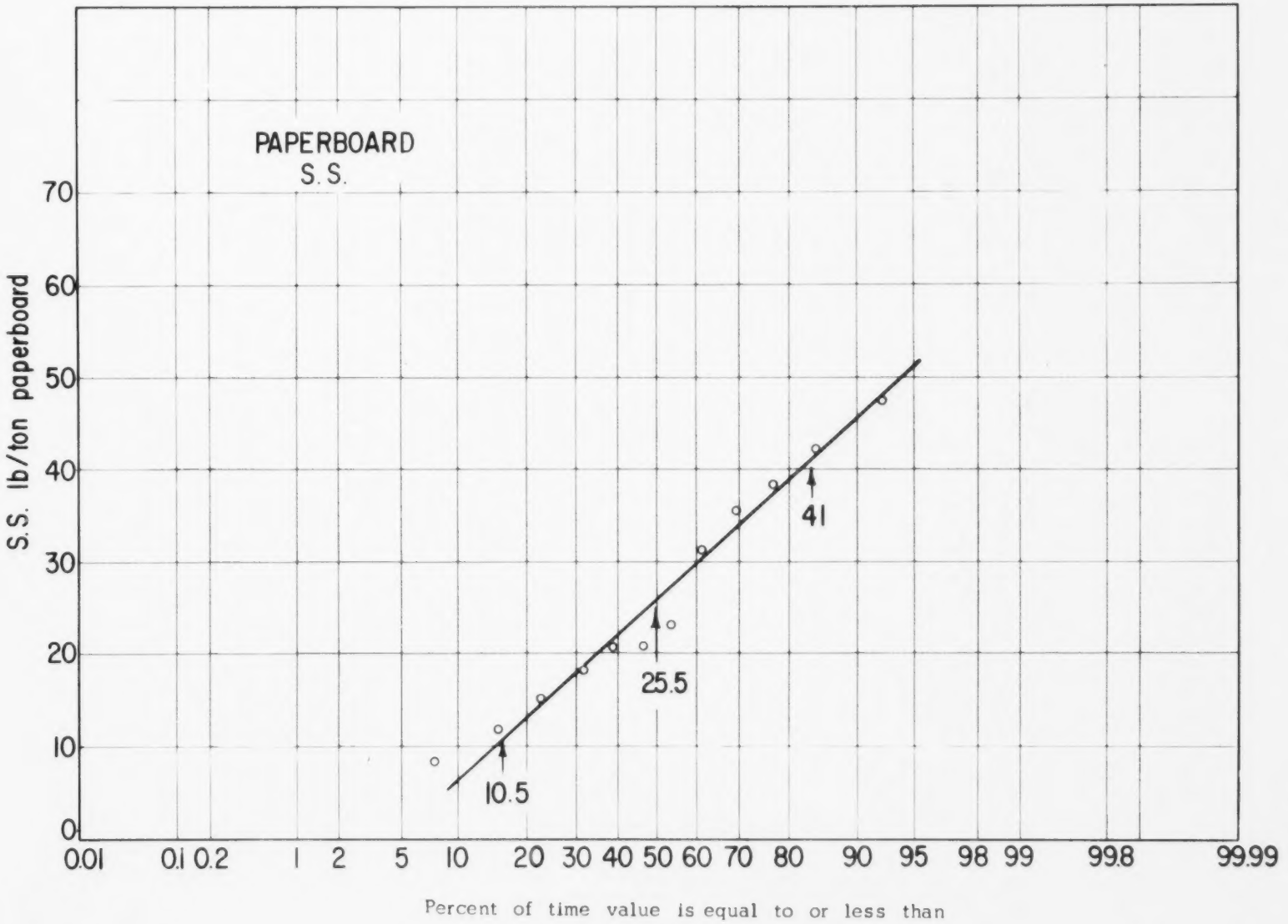

SYNTHETIC FIBERS
BOD
BOD – lb/1000 lb each process
1000
500
100
50
10
21
62
190
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

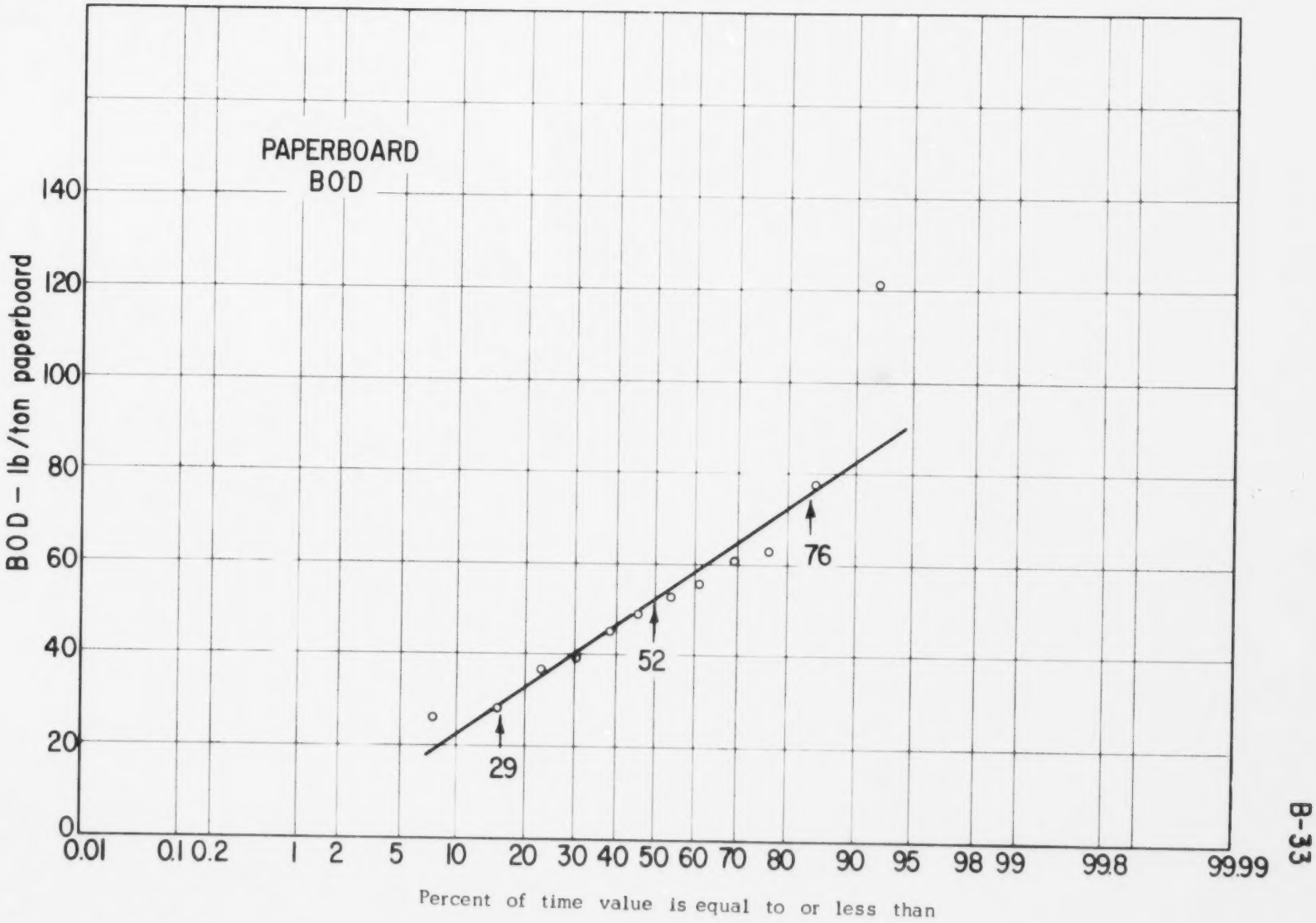

TEXTILE WASTE
FLOW
5000
1000
500
100
50
10
110
450
1900
FLOW - gal / 100 lb goods
5
10
20
30
40
50
60
70
80
90
95
Percent of time value is equal to or less than

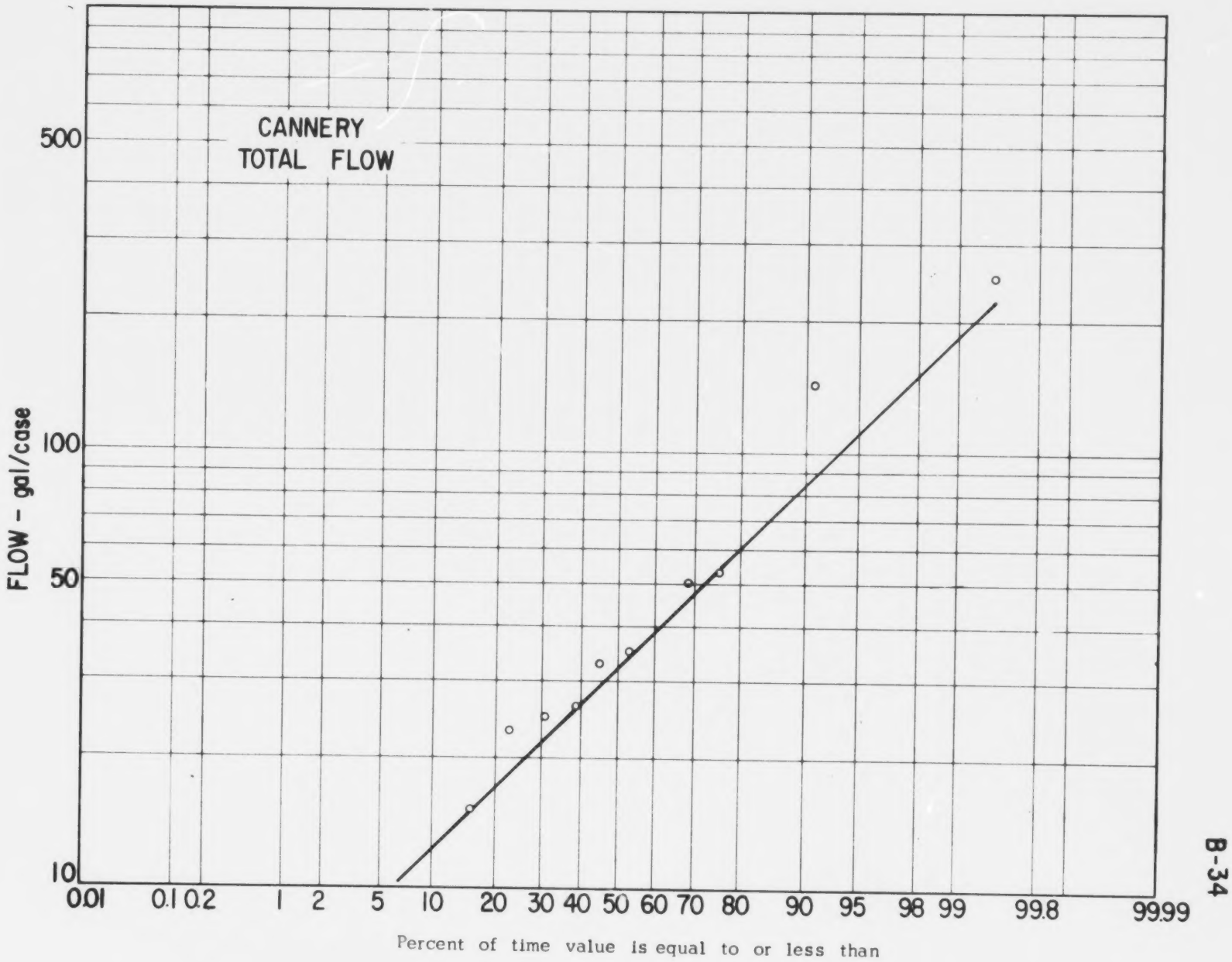

TEXTILE WASTE
BOD
100
50
10
5
1.0
0.5
0.1
BOD_5 - lb/100 lb goods
0.47
1.2
5
10
20
30
40
50
60
70
80
90
95
Percent of time value is equal to or less than

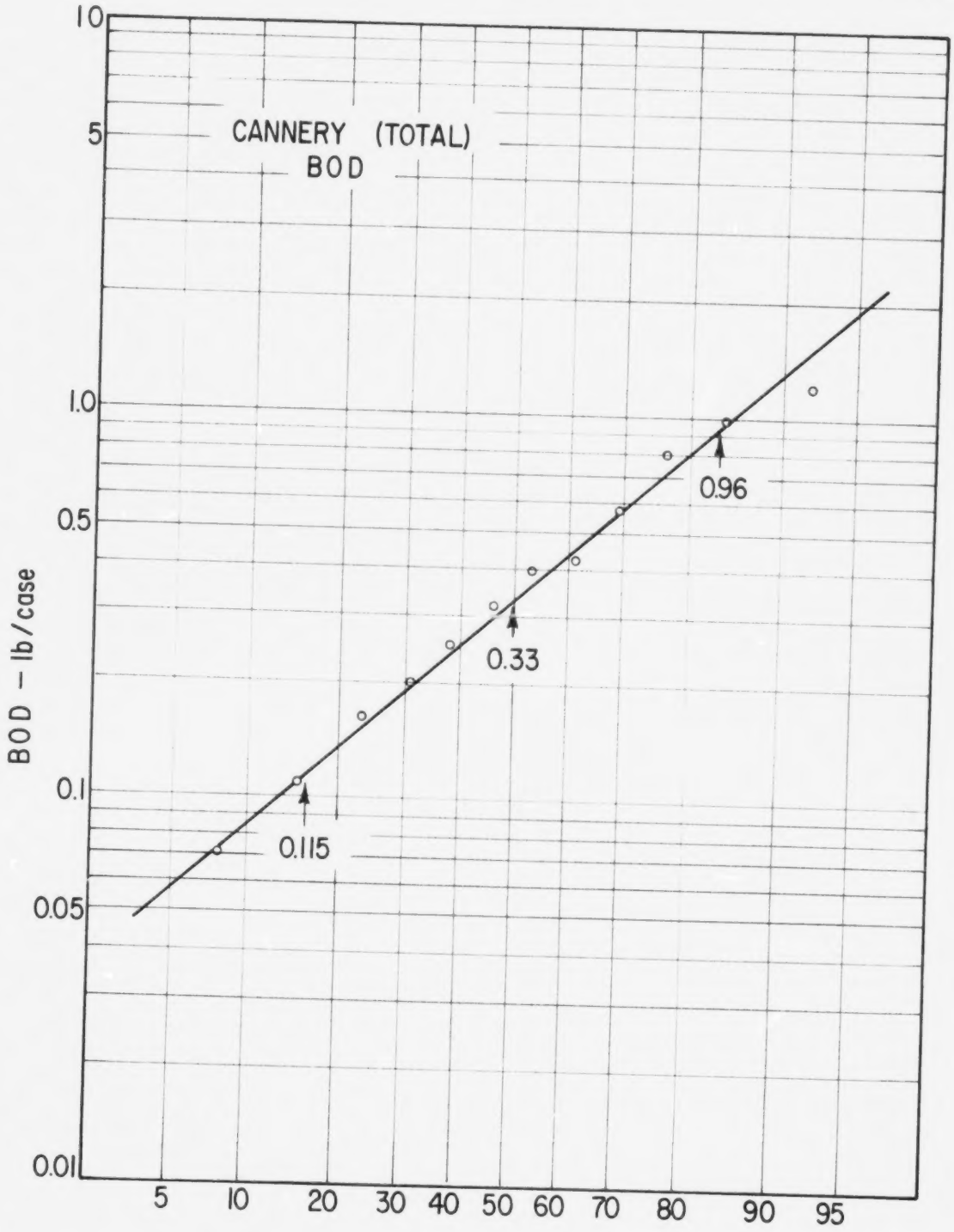

TEXTILE WASTE
S. S.
S. S. - lb/100 lb goods
10
5
1.0
0.5
0.1
0.19
0.49
1.3
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.99
Percent of time value is equal to or less than

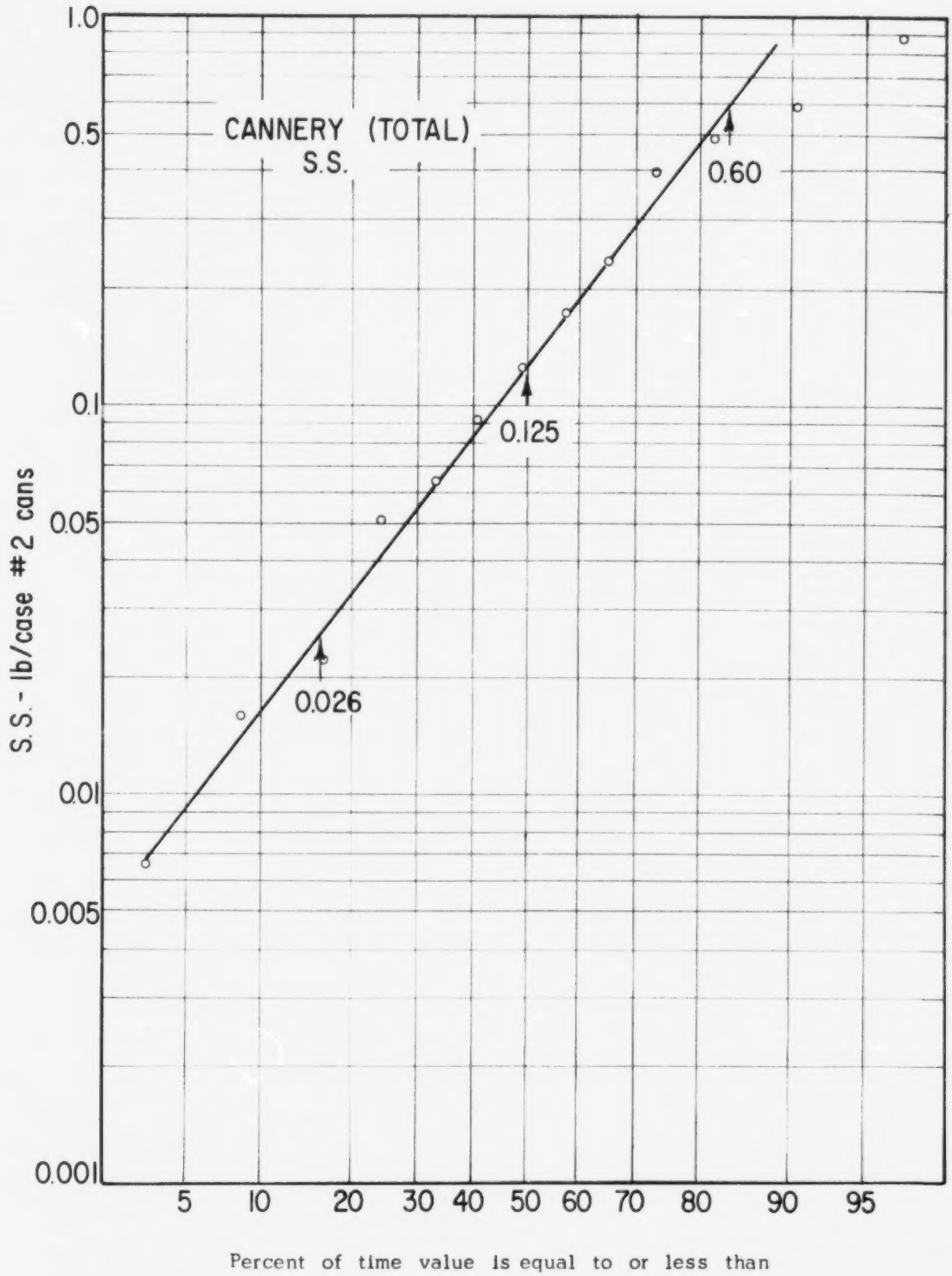

TEXTILE WASTE
TOTAL SOLIDS
TOTAL SOLIDS - lb/100 lb goods
100
50
10
5
1
5.5
15.5
43
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

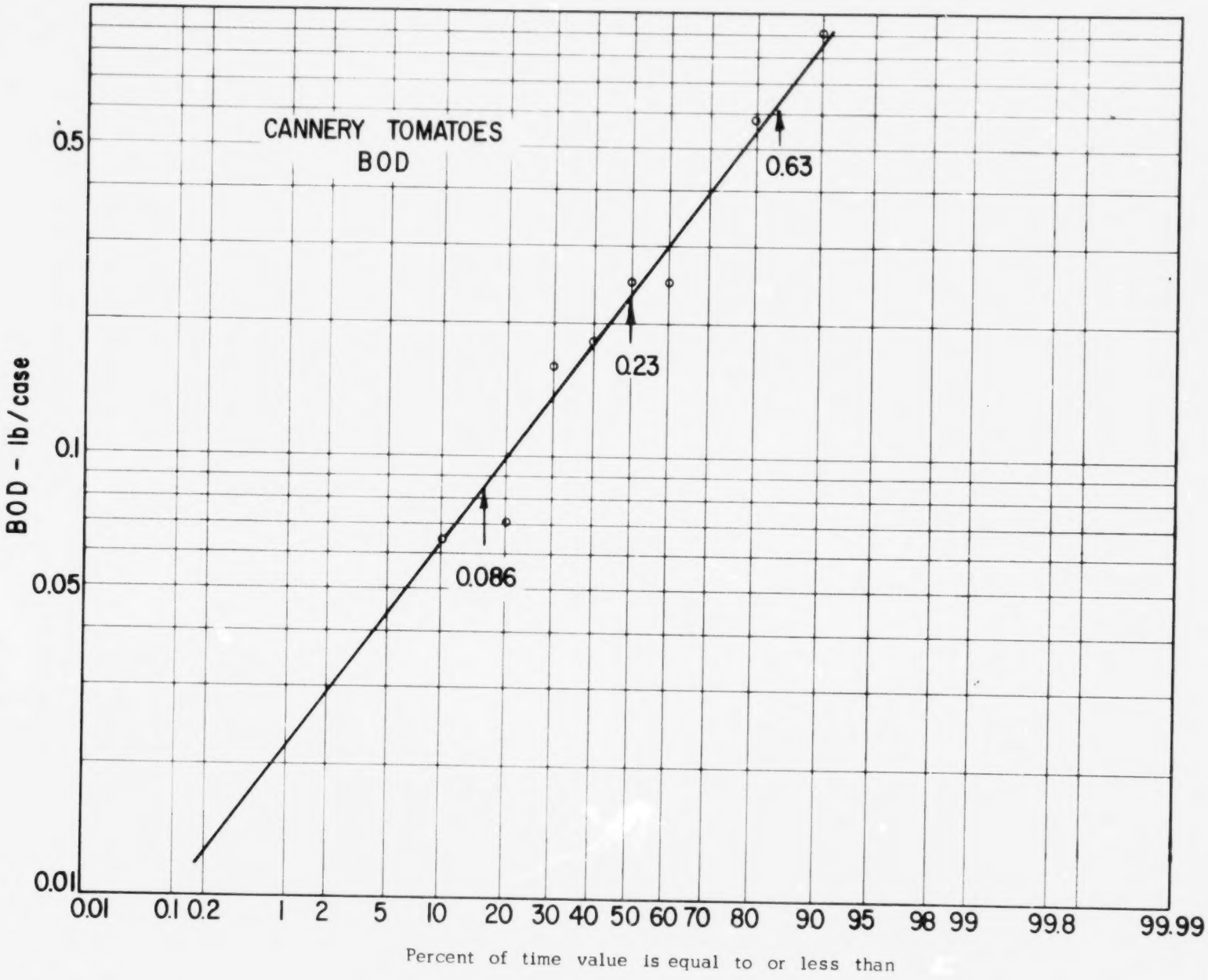

PAPERBOARD
S.S.
S.S. lb/ton paperboard
0
10
20
30
40
50
60
70
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
10.5
25.5
41
Percent of time value is equal to or less than

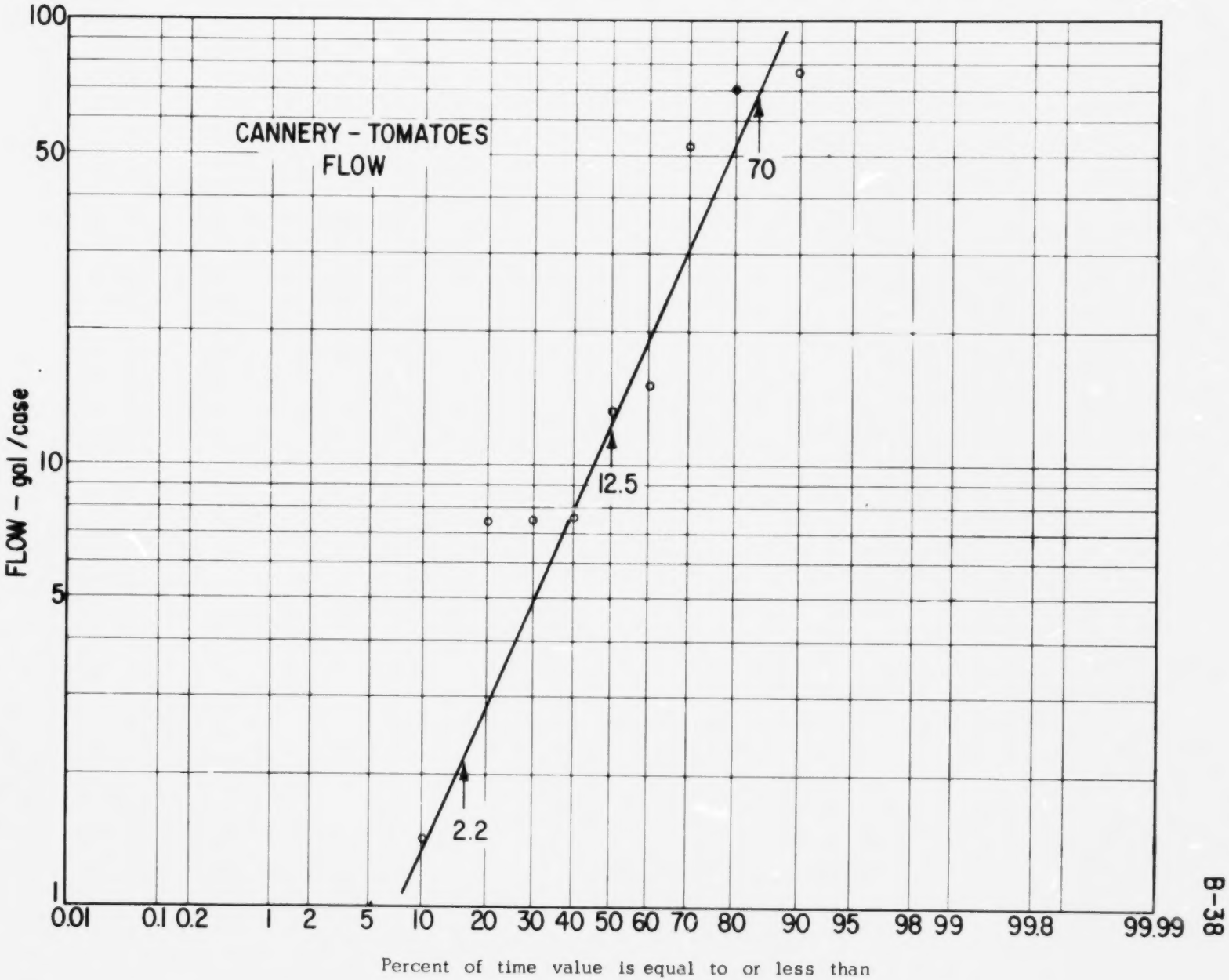

PAPERBOARD
BOD
BOD – lb/ton paperboard
140
120
100
80
60
40
20
0
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
29
52
76
Percent of time value is equal to or less than

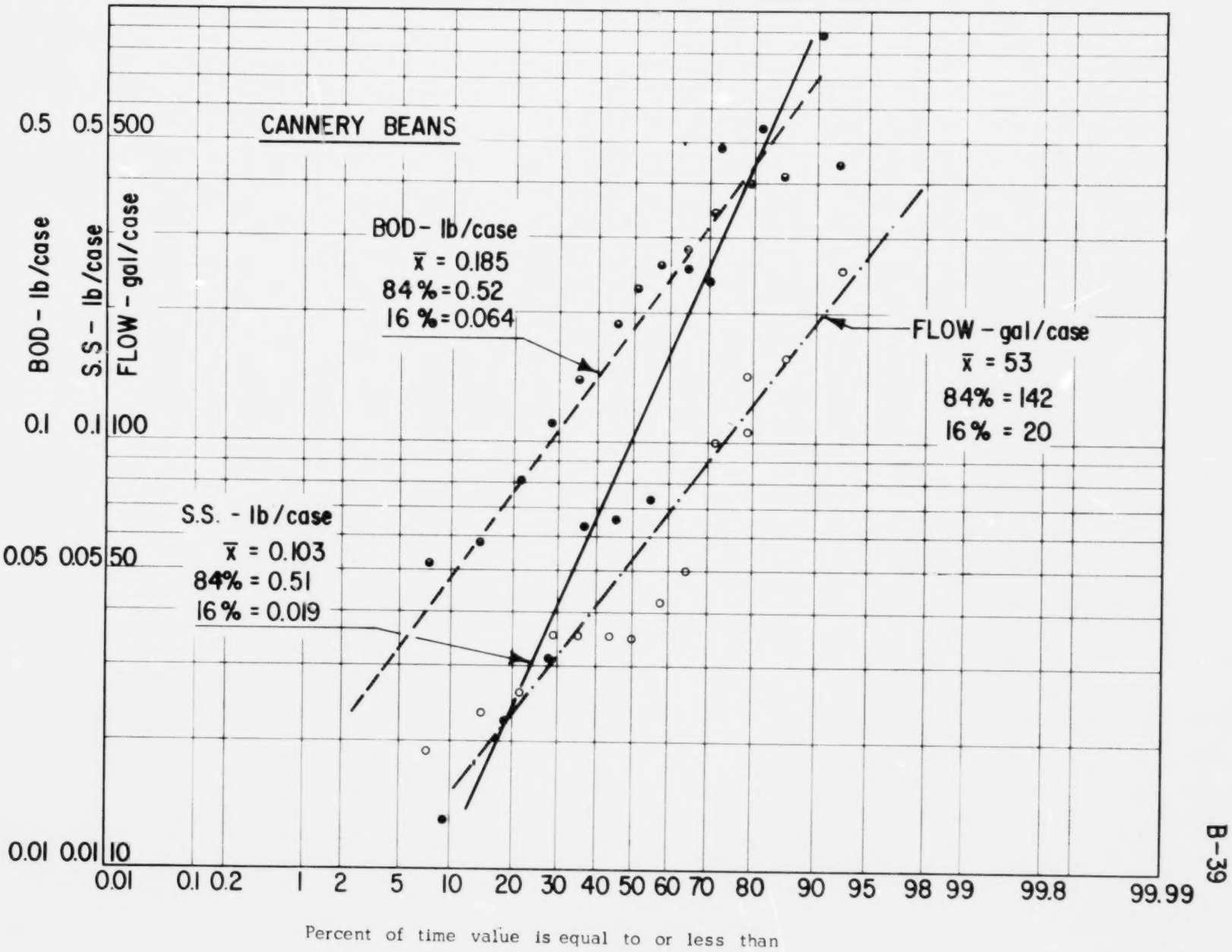

CANNERY
TOTAL FLOW
FLOW - gal/case
500
100
50
10
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than

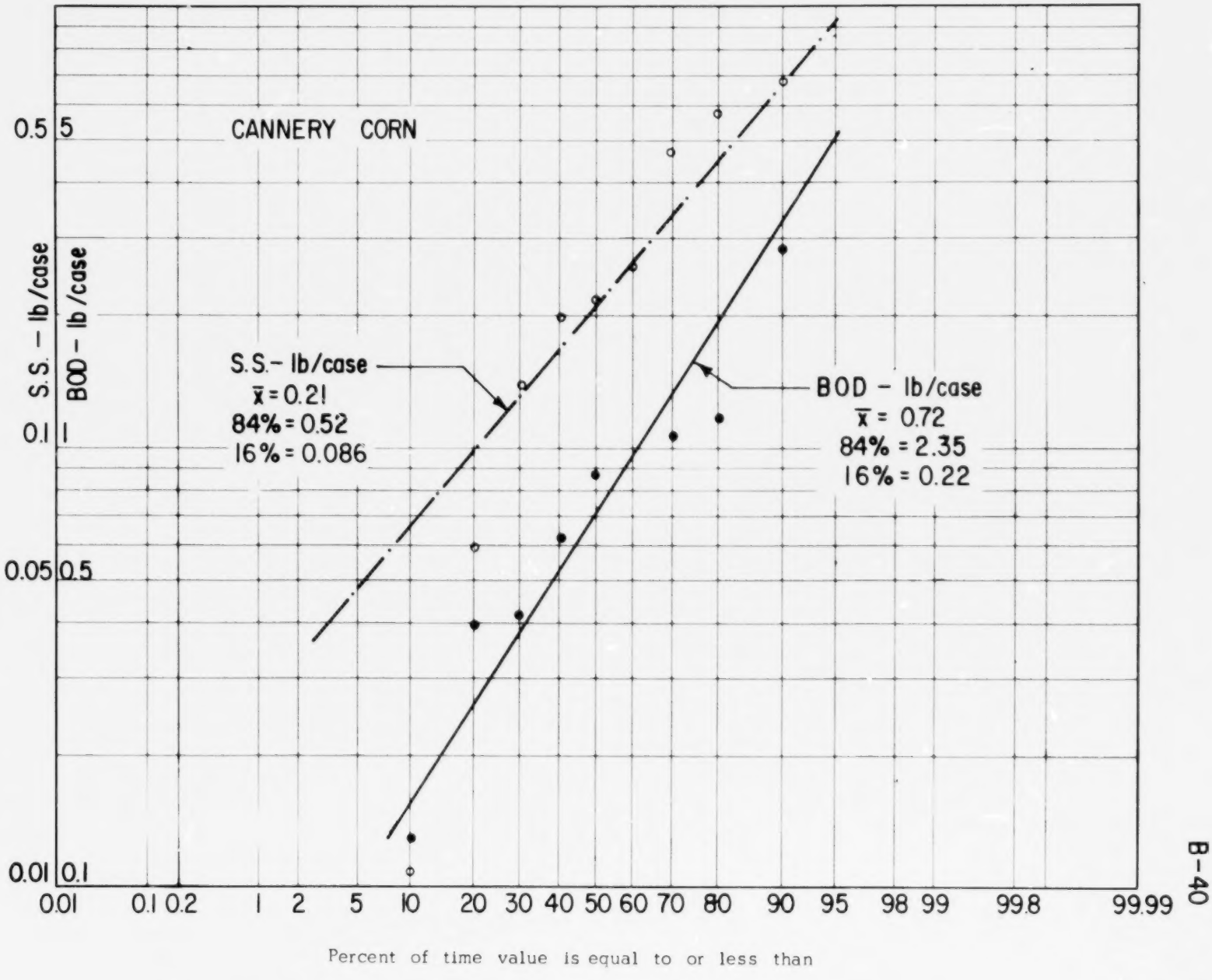

CANNERY (TOTAL)
BOD
BOD – lb/case
10
5
1.0
0.5
0.1
0.05
0.01
0.115
0.33
0.96
5
10
20
30
40
50
60
70
80
90
95
Percent of time value is equal to or less than

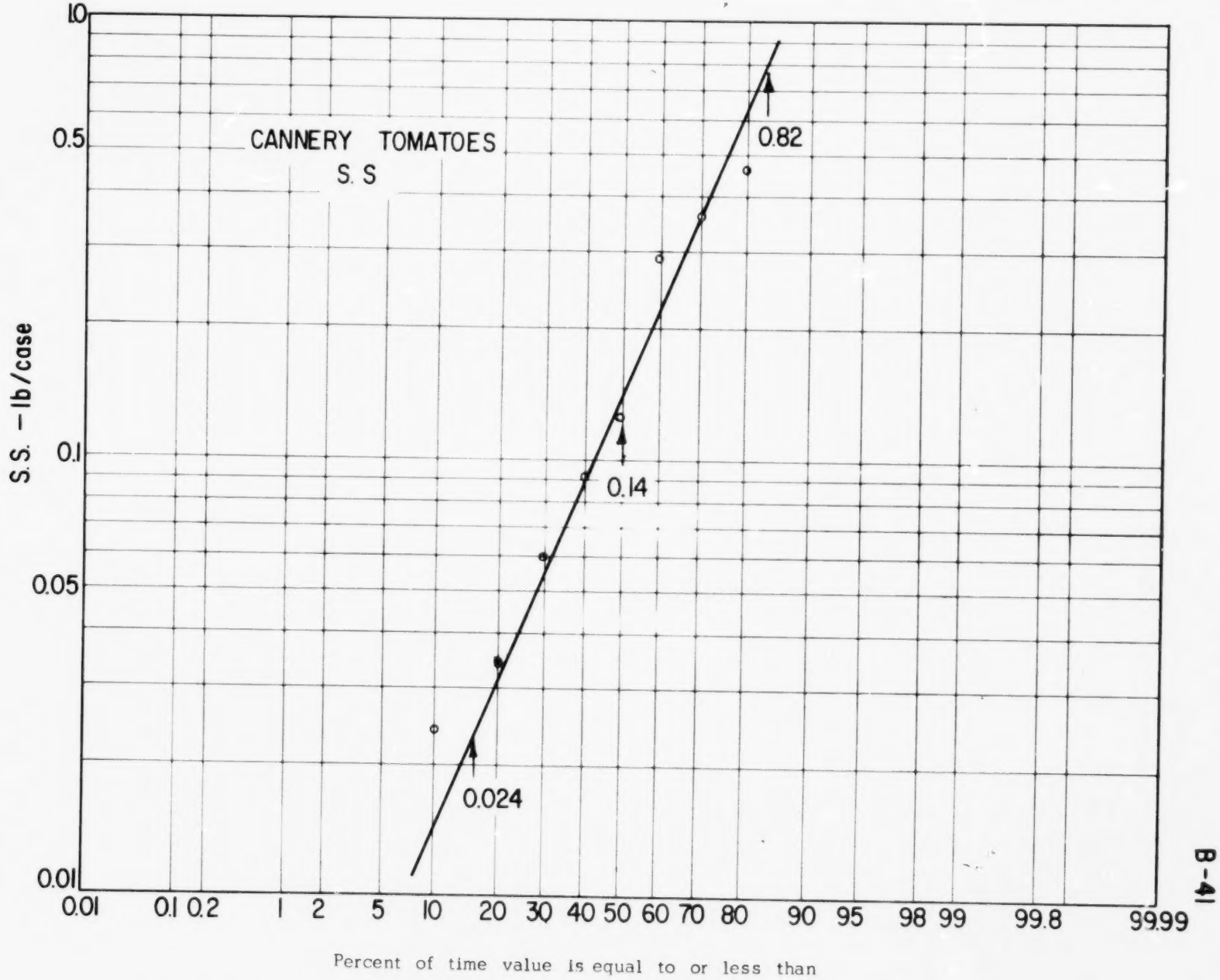

CANNERY (TOTAL)
S.S.
0.60
0.125
0.026
S.S. - lb/case #2 cans
1.0
0.5
0.1
0.05
0.01
0.005
0.001
5
10
20
30
40
50
60
70
80
90
95
Percent of time value is equal to or less than


CANNERY TOMATOES
BOD
0.63
0.23
0.086
BOD - lb/case
0.5
0.1
0.05
0.01
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.99
Percent of time value is equal to or less than


CANNERY - TOMATOES
FLOW
FLOW - gal /case
100
50
10
5
1
2.2
12.5
70
0.01
0.1
0.2
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.99
Percent of time value is equal to or less than


CANNERY BEANS
BOD - lb/case
$\bar{x}$ = 0.185
84% = 0.52
16% = 0.064
FLOW - gal/case
$\bar{x}$ = 53
84% = 142
16% = 20
S.S. - lb/case
$\bar{x}$ = 0.103
84% = 0.51
16% = 0.019
BOD - lb/case
S.S - lb/case
FLOW - gal/case
0.5 0.5 500
0.1 0.1 100
0.05 0.05 50
0.01 0.01 10
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.99
Percent of time value is equal to or less than


CANNERY CORN
S.S. – lb/case
BOD – lb/case
S.S.– lb/case
x̄ = 0.21
84% = 0.52
16% = 0.086
BOD – lb/case
x̄ = 0.72
84% = 2.35
16% = 0.22
0.5 5
0.1 1
0.05 0.5
0.01 0.1
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.99
Percent of time value is equal to or less than


CANNERY TOMATOES
S. S
0.82
0.14
0.024
S.S. - lb/case
1.0
0.5
0.1
0.05
0.01
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.99
Percent of time value is equal to or less than

Products	Flow Rate MGD	BOD_{in} ppm	BOD_{out} ppm	SS_{in} ppm	SS_{out} ppm	COD_{in} ppm	COD_{out} ppm	Opt'n x10
Herbicides	0.1							25
Butadiene Maleic Acid	2.0	2,000	25	10	80	2,990	480	47
Corrosion Control Rust Preventive Materials	0.05							8
Soda Ash Cl_2 Caustic	4.0			15,000	100~200			100
Para-Cresol	36,000 gal/day	-	Sulfite Liquors					50
Beta-Naphthol	19,000 gal/day	-	Sulfite Liquors					30
Drugs	0.8	130	125	8,000	7.6	1,100	1,050	200
Plastics	1.69	686	186			1,681	590	100
Butadiene Alkylate	2.16	300	150	-	70	500	250	74
Drugs	1.25~1.5	1700~2300	375~750	500~1200		4000~5500		170
Resins	0.5		500		200			5
Amines, Amides	0.6	150	140	30	3	1,300	1,200	240
PVC Plastics	0.801	150	60	500	20~40	1,200	600	45
Organics	5.3	2,100	1,030	600	-	4,400	2,640	-
Pigments, H_2SO_4	0.5		34	400	2,700	1,120	1,120	275 25 1,200
Butadiene Olefins	1.89							142
Butadiene Olefins	1.40							
Resin	0.17	500~1400	10		5-10			
Phenol, Salicylic Acid, Rubber Chem., Aspirin	2.59	190	6.1					350
Rayon + Sanitary	3.6	120	42	30	60	300	105	40
Cellophane	4.32	114	29	32	60	210	53	25
Raw Plastics, Oils + Sewage	0.1	4,800	20	-	-	6,500	1,000	10

Table C-1
Treatment Performance and Costs of Co
Chemical Industry

COD_{in} ppm	COD_{out} ppm	Opt'n Cost $x10^3$	Const'n Cost $x10^3$	Treatment Processes	Reference
		25	51.5	Chlorination Followed by Neutralizing with Lime, Settling + Incineration	Private Communication
990	480	47	616	Extended Aeration, Activated Sludge, Sludge Disposal by Anaerobic Lagoon	Private Communication
		8	10	Batch Tanks for Chrome Removal, pH Adjusting, Settling Pond, Landfill	Private Communication
		100	2,250	10 Settling Ponds (260 Acres Total), Build Up Dikes as Landfills for Sludge Disposal	Private Communication
		50	123	Mixco Agitator With Sparge Ring - Oxidation	Private Communication
		30	93	Mixco Agitator with Sparge Ring - Oxidation	Private Communication
00	1,050	200	400	pH Control, Settling, Landfill for Solids	Private Communication
81	590	100	665	Facultative Ponds, Landfill & Burning	Private Communication
00	250	74	1,672	Lagooning (No Aeration), API, Landfill	Private Communication
5500		170	1,500	Grit Removal, Equal., Neutr., Flotat., Act. Sludge + Trick. Filter, Aerobic Digestion, Landfill	Private Communication
		5	170	Primary Settling	Private Communication
00	1,200	240	360	Settling, Landfill, Neutral., Arsenic Removal Vacuum Filter, Equalization	Private Communication
00	600	45	300	Grit Removal - Neutralization with Lime - Coag. with Alum Settling - Sludge Dewatering, Sludge Lagoons	Private Communication
00	2,640	-	992	Aeration - Settling	Private Communication
		279	665	Settling, Neutral., Landfill	Private Communication
		25	65	Lagoons, Landfill	
00	1,120	1,200	4,200	Barge to Sea	
		142	166	Lime + Alum, Coag., pH Adjustment, Filtration through Diatomaceous Earth, Sludge by Ponding	Private Communication
			133	Lime Coagulation - Ponding	Private Communication
				Activated Sludge - T.F. - Ponding	Private Communication
		354.5	1,792	Neutralization with Lime, Clarification, Trickling Filter, Activated Sludge, Sand Filter	124
0	105	40	350	Nutrient Feed, Aerated Lagoon (Basin Was Already Built)	Private Communication
0	53	25	800	Neutralization, Nutrient Feed, Contact Stabilization, Clarification	Private Communication
0	1,000	10	2,250	Comminutor, Extended Aeration + Nutrient - Stabilization Pond	Private Communication

able C-1
and Costs of Construction and Operation -

Products	Flow Rate MGD	BOD_{in} ppm	BOD_{out} ppm	SS_{in} ppm	SS_{out} ppm	COD_{in} ppm	COD_{out} ppm	$Phenols_{in}$ ppm	$Phenols_{out}$ ppm
Chemical	0.1	17,000	100						
Chemical	0.15	1,950	200						
Organics, Pesticides	0.35			100-300	100-300	1000-3000	50-150		
Plastics, Enzymes, Amines	1.06	1,960	37	20-100	5-30	2,660	230		
Drugs, Synth. Organics	1.25	2,500	500	800	250	5,500	2,500		
Drugs	0.55	301	60	171	76				
Chemicals	3.57	156	10						
			-	-	-				
[a] Gasoline	0.27	440	5			500	60	25	1.0
Polyester Fibers	0.6	3,750	100	700	50				
Polyester Fibers	0.325	2,350	75	600	100				
Nylon	0.4	1,540	250	576	75				
Cellulose, Acetate	3.0	1,060	308	136	457				
Petrochemical	1.45	2,000	25	0	104	3,000	480		
Butadiene, Alkylate	1.5	1,960	24	1,530	100	2,980	477		
Fine Chemicals	1.0	1,900	50	1,000	20				
Chemicals for Lubricating Oils	0.2	465	180	250	65	1,050	600		

[a] Water from Condensate AFter Oil Quench

Table C-1
Treatment Performance and Costs of
Chemical Industry

$Phenols_{in}$ ppm	$Phenols_{out}$ ppm	Opt'n Cost $x10^3$	Const'n Cost $x10^3$	Treatment Processes	Reference
				Extended Aeration	Private Communication
				Extended Aeration	Private Communication
		200	>1,000	pH Adjustment, Settling, Mixing, Act. Sludge, Clarifier	Private Communication
		299	1,500	pH Adjustment-Equalization-2 Trickling Filters-4 Lagoonings Landfill (Land Costs Not Included)	Private Communication
		225	2,640	Sludge Disp.-Aerobic Digest., Spray Irrigation	Private Communication
		42	661	Contact Stabilization, Landfill	Private Communication
			1,200	Neutralization-Nutrient Addition-Thickener-Centrifuge-Contact Stabilization	Private Communication
	1.0			Activated Sludge	Private Communication
		50	500	Equalization-Modified Extended Aeration-Oxidation Ponds-Aerobic Digest. Landfill	Private Communication
		30	340	Equalization-Modified Extended Aeration-Oxidation Ponds-Aerobic Digest. Landfill	Private Communication
		40	373	Extended Aeration, Digestion, Landfill	Private Communication
		38	600	Stabilization-Aerated Lagoons-Landfill	Private Communication
		-	-	Act. Sludge, NH_3 Added	Private Communication
		120	620	Extended Aeration-Activated Sludge Lagoons	Private Communication
		-	1,000	Grit Chamber, Clarifier, Activated Sludge Polishing Pond, Nutrient Addition, Chlorination	Private Communication
		84	283	Neutralization-Clarification-Aerated Lagoon Landfill for Sludge Disposal	Private Communication

Table C-1
ce and Costs of Construction and Operation -
ry

B

Products	Flow Rate MGD	BOD_{in} ppm	BOD_{out} ppm	SS_{in} ppm	SS_{out} ppm	COD_{in} ppm	COD_{out} ppm	Opt'n Cost $x10^3$	Const'n Cost $x10^3$	Treatment Processes	Reference
Fatty Acids	0.65		150		120	~1,440	290	43	70	Fats Separation - Settling, Solids Are Soluble	Private Communication
Sebacic Acids	0.25		1,370	6,000	0	2800-3800	1,900		170	Equalization, Neutralization, Lagooning Sludge Lagooning for 15-20 yrs	Private Communication
Chemical	0.2								400	Neut., Coagulation, Clarification	Private Communication

Table C-1
Treatment Performance and Costs of Construction and Operation -
Chemical Industry

Flow Rate	BOD_{in} ppm	BOD_{out} ppm	SS_{in} ppm	SS_{out} ppm	pH_{in}	pH_{out}	Treatment Processes	References
135,000	600	10	160	90	11.0	7.8	Batch Aeration	32
64,500	820-620	20~220	460~360	90-1150	7.4~7.6	7.4~7.6	Grit Chamber + Equalization + Aeration + Settling	32, 123
150,000	730	210	770	70	6.8~7.6	7.3	Clarifier - 2 T.F. - Clarifier - T.F.	32
151,000	400	100	82	66	7.6	7.6	Lagooning with Spray of Wastes to Air for Aeration (Aerated Lagoon)	32
361,000	100	25	-	-	-	-	Aerated Lagoon	-
2,700	350	140	190	130	6.2	7.4	Clarifier, T.F., Digester, Drying Beds	32

Table C-1
Treatment Performance and Costs of Construction and Operation - Dairy

Flow MGD	BOD_{in} ppm	BOD_{out} ppm	SS_{in} ppm	SS_{out} ppm	COD_{in} ppm	COD_{out} ppm	$Grease_{in}$ ppm	$Grease_{out}$ ppm	Nitrogen as N_{in} ppm	Op
-	2,328	44								
	1,934	31								
	1,860	43								
	1,135	82								
	1,430	490								
	1,720	1,250	2,780	1,890			675	405		
	2,600	530	2,075	685			1,135	35		
1.41	1,381	26	988	23						
0.45~0.60	3300~4000	177~195	1650~6600	110~140	5320~6550	290~320	700~4000	120~190		
0.60	2200~2600	180~200	2,000	200						29.6 23.7
0.85	1,765	17.7	3,020	80			1,480	21.0	95.2	40
0.408	940	20	457	88	1,285				80	

Table C-1
Treatment Performance and Costs of Constr
Meat Packing Industry

ase $_{out}$ ppm	Nitrogen as N_{in} ppm	Opt'n Cost $x10^3$	Const'n Cost $x10^3$	Treatment Processes	Reference
				Anaerobic Pond-Recovery Pond-Aerobic Pond	17
				Anaerobic Pond-Anaerobic Pond (Partial Aerobic)-Anaerobic-Anaerobic-Anaerobic Pond	115
405				Screening	
135				Screening-Anaerobic Lagoon	4
				Anaerobic Contact-Oxidation Ponds (Flow Rate from Pond is 0.772 MGD)	114
190		0.55	45.4	Anaerobic Lagoon (5 Acre Surface, 14' Depth) Sludge Disposal in Lagoon	Private Communication
		29.6 in '64 23.7 in '65	451	Anaerobic Contact Pretreatment. Effluent Goes to City Aerobic Facilities, Landfill	Private Communication
21.0	95.2	40	182	Primary-Balancing Tank-Anaerobic Digester-Oxidation Pond	73
	80			Screening, Grease Skim, Anaerobic Pond, Aerobic Pond	94

Table C-1
ce and Costs of Construction and Operation -
dustry

Industry	Flow gpd	BOD_{5in} ppm	BOD_{out} ppm	COD_{in} ppm	COD_{out} ppm	$Phenol_{in}$ ppm	$Phenol_{out}$ ppm	Total N_{in} ppm	Total N_{out} ppm	SS_{in} ppm	SS_{out} ppm	Costs $x10^3$$ Constr./yr	Oper./yr	Treatment	Reference
Iron and Steel Coke Oven	430,000	1,400	10	1,800	-	500	10	262	14	-	-	-	292	Trickling Filters, Ion Exchange	52
Poultry Packing	100,000	653	16					91	20	653	23	72.8		Screen, Clarifier, Trickling Filters, Clarifiers	107

Table C-1
Treatment Performance and Costs of Construction and Operation - Miscellaneous Industries

Waste	Flow Rate MGD	BOD_{in} ppm	BOD_{out} ppm	COD_{in} ppm	COD_{out} ppm	$Phenols_{in}$ ppm	$Phenols_{out}$ ppm	$Sulfides_{in}$ ppm	$Sulfides_{out}$ ppm	(in ppm
Total Refinery	1.76	-	-	384	151	8.5	0.7	15.0		
" "	1.69		109	287		55	2.1	2		
" "	5.85			280	230	15	4.0			
" "	0.092			2,020	1,138	237	53	40	3	
Process Waste + Domestic	0.20	122		48	15	8	0.25			
Total Refinery	1.01	1.1	34		176	11.4	0.3			Oils in 20
" "	0.22	200	26	250	100	12	0.5			Oils in 50
" "	0.77			272		85	3.0			
" "	1.76			157	54	0.7	0.1			
" "	0.304			1,000	330	190	0.3			
" "	0.07					125	0.02			
" "	0.058			4,000	1,200	800	10	300	0	
" "	0.044					600	5	200	0.8	
" "	1.72	109	60			2	0.1			
" "	0.29			700	250	30	0.5			Oils in 50
" "	1.16	109	10	314	50	5.7	0.02	7.2	0	76
" "	-	175	42	467	146	7.4	0.4	8	0.2	197
" "	2.45	345	75	855	175			150		
" "	3.74	190	80	534	210	36				Oils in 61
" "	15.0	227	100	976	300					
" "	2.60	45	35	300	235					SS in 100

Table C-1
Treatment Performance and Costs of Co
Petroleum Industry

Sulfides$_{out}$ ppm	Miscellaneous (in ppm unless otherwise indicated)				Opt'n Cost x10^3	Const'n Cost x10^3	Treatment Processes	References
							T.F. 2:1 Recycle	7
							T.F. 1.5:1 Recycle	7
							T.F. 1:1 Recycle	7
							T.F. 0.3:1 Recycle (plastic media)	7
3								
							T.F. No Recycle	7
	Oils in 20	Oils out 9	Temp in 88°F	Temp out 86°F			Complete Mixing, Sludge Return Act. Sludge, 2.9 hr aeration	7
	Oils in 50	Oils out 2	Temp in 95°F	Temp out 95°F			Complete Mixing, Sludge Return Act. Sludge, 2.8 hr aeration	7
			Temp in 82°F	Temp out 82°F			Complete Mixing, Act. Sludge with Return, 13.6 hr aeration	7
			Temp in 94°F				Completely Mixed Act. Sludge, with Return	7
			Temp in 100°F	Temp out 90°F			Completely Mixed Act. Sludge, with Sludge Return	7
			Temp in 98°F	Temp out 95°F			Completely Mixed Act. Sludge, with Sludge Return	7
							Completely Mixed Act. Sludge	7
0							Completely Mixed Act. Sludge	7
0.8							Conventional Act. Sludge	7
	Oils in 50	Oils out 40					Conventional Act. Sludge	7
			NH_3 in	NH_3 out			Oil Separation - Aeration - Oxidation Ponds	7
0	76	10	32	18			Oil Skimming, Aerated Lagoon Settling	-
0.2	197	22	20	22			Aerated Lagoon	Private Communication
	Oils in 61		Temp in 74°F				Aerated Lagoon	Private Communication
			90°F				Aerated Lagoon	Private Communication
	SS in 100	SS out 50			150	874	API, Settling, Neutral., Activated Sludge, Holding Ponds, Landfill	Private Communication Private Communication

ble C-1
nd Costs of Construction and Operation -

Waste	Flow Rate MGD	BOD_{in} ppm	BOD_{out} ppm	COD_{in} ppm	COD_{out} ppm	$Phenols_{in}$ ppm	$Phenols_{out}$ ppm	$Sulfides_{in}$ ppm	$Sulfides_{out}$ ppm	(in ppm unless	Mis
										SS in	SS out
Total Refinery	10.5		80	977	259					109	38
" "	4.7		21	380	114					65	24
" "	26.65	70	14							12	-
" "	2.88										
Petrochem.	1.08	155	30	380	300					120	30
Refinery	0.389	1,600	0-8.2	1200-2350	127-154	40-80	0.003				15-32
Refinery + Petrochem. + Sanitary	5.0	125	28	360	109	14	0.1	30	0	100	21
"	3.1		<10	600	300						20

Table C-1
Treatment Performance and Costs of Const
Petroleum Industry

Sulfides$_{out}$ ppm	Miscellaneous (in ppm unless otherwise indicated)				Oper. Cost $ x 10^3	Const. Cost $ x 10^3	Treatment Processes	Reference
	SS in 109	SS out 38			608.5	7,640	API, Coagulation, Settling Vacuum Filtration, Incineration	Private Communication
	65	24			216.4	1,540	API, Coagulation, Flotation, Vacuum Filtration, Incineration	Private Communication
	12	-				2,690	API, Flotation, Activated Sludge, Settling	Private Communication
					120	1,500	API, 2 Units Flotation, Vacuum Filtration	Private Communication
	120	30			40	276	API (2), Hay Filter, Sludge to Lagoons, Landfill	Private Communication
		15-32	NH_3 out 3.9-5.6	NO_3 out 27			Oil Separator, Aeration + Equalization, Trickling Filter, Ozone Oxidizer, Holding Basin, Sand Filter	Private Communication
0	100	21	Oil in 50	Oil out 0	51.6	1,056	Chemical Treatment, Extended Aeration, Holding Pond, Sludge Dewatered in Lagoon, Landfill	Private Communication
		20			25	300	API, Flotation, Aerated Lagoon, Clarification (Note: Existing Reservoir Used for Aeration Basin at No Change)	Private Communication

able C-1
and Costs of Construction and Operation -

Products	Flow Rate MGD	BOD_{in}	BOD_{out}	SS_{in}	SS_{out}	COD_{in}	COD_{out}	TS_{in}	TS_{out}	Opt'n Cost $x10^3$	Const'n Cost $x10^3$	Treatment Process	Reference
Paper	11.4	250	150	1,260	350			2,110	1,200			Primary Clarifier Only	3
Board	1.38	655	60	570	87					42.7	474	Primary Clarifier-Nutrient Add.-Aerated Lagoon Irrigation Field-T.F.-Sedimentation-Final Aeration	1
Kraft	10.9	274	33	505	124								
	10.4	233	34	710	167							Clarifier-Aeration-Clarifier	15
Board	5.0	175	149	325	98							One Hr. Plain Settling	7[2]
-	0.56	500	125									Activated Sludge	8
Unbleached Kraft Board and Paper	25	200	50	350	32	334				100	1,480	Settling Pond-Aerated Lagoon-Landfill	8
Fine Paper		288	29									Trickling Filter	-
Board		218	28									Trickling Filter	
Deinking		252	30									Trickling Filter	
Kraft Pulp and Paper	23.7	144	-								1,000	Clarifier + Centrifugation + Incineration	Private Communication
Board	2.5	180	20	800	100							Activated Sludge	" "
Pulp and Paper	24	260	36	1,050	108	1,560	450					Act. Sludge, Vacuum Filtration, Landfill	" "
Kraft and Paper	22	320	60	1,000	250					350	4,920	Act. Sludge, Vacuum Filtration, Landfill	" "
Paper	11.72	302	200	1,243	293						510	Primary Treatment, Vacuum Filter	" "
Kraft and Paper	8.5***	**	130			**	*220			200	2,105	Trickling Filter, Primary Clar., V.F., Thick., Chlor., Landfill (6.5 MGD p&p. 2.0 MGD Sanitary)*** **250 ppm p&p, 150 ppm, Sanitary *300 ppm p&p, Sanitary Unknown	" "
Kraft - Unbleached Pulp	30	273	218	227	19					144	1,027	Screening, Pumping Station + Clarifier, 2 Centrifuges, Landfill	" "
Unbleached Kraft Paperboard	9.65	200	15	.95	20	210	110			20	500	Primary Treatment + Aerated Lagoon	" "
Kraft and Paper	3.0	250	90	1,200	150					140	840	Primary Clarifier + Aerated Lagoon, Lagoon Sludge Disposal	" "
Sulfite Pulp Fine Paper	7.5	145	50	350	30						550	Clarification, Complete Dewatering System	" "
Papers	10	350	77								696	Primary Treatment, Aerated Lagoon	" "
"	10	350	18								816	Primary Treatment, Act. Sludge	" "
"	10	350	14								880	Primary Treatment, Contact Stabilization	" "
Groundwood, Kraft, Paper	40										1,910	Primary Clarifier, Centrifuge	" "
Groundwood, Paper	12										500	Primary Clarifier, Centrifuge	" "
Sulfite Pulp and Paper	60										2,000	Primary Clarifier, Vacuum Filter	" "

Table C-1
Treatment Performance and Costs of Construction and Operation - Pulp and Paper Industry

DAILY OPERATING COST - INDUSTRIAL WASTE TREATMENT

APPENDIX C-2

Industry	Flow Rate MGD	Type of Treatment	Daily Operating Cost (Exclusive of Amortizat.) $/MG	$/1000 lb Pollut.*
Refinery		Primary Treatment		
	10.5	API - Coag. - Settling - Sludge Filtration - Incineration	160	26(3)
	4.7	API-Coag.-Flotation-V.F.-Incineration	126	59(3)
	1.08	API-API-Hay Filter-Sludge Lagoon-Land Fill	137	152(3)
	2.88	API- 2 Flotation-V.F.	142	-
		Secondary Treatment		
	2.60	API-Settling-Neutralization-Activated Sludge Holding Ponds-Land Fill	161	292(3)
	5.0	Chemical Addition- Extended Aeration-Holding Pond	28	14(3)
	3.1	API-Flotation-Aerated Lagoon-Clarification	22	9(3)
Pulp & Paper		Primary Treatment		
	30	Screening-Pumping Station-Clarifier-2 Centrifuges-Landfill	13	29(1)
		Secondary Treatment		
	3.0	Primary Clarifier-Aerated Lagoon-Lagooning for Sludge	101	96(1)
	9.65	Primary Treatment-Aerated Lagoon-No Sludge Disposal	6	4(1)
	25	Settling Pond-Aerated Lagoon	11	9(1)
	1.38	Primary Clarifier-Nutrient Addition-Aerated Lagoon-Irrigation-T.F.-Settling-Final Aeration	85	17(1)
	24	Activated Sludge -V.F. -Land Fill	57	31(1)
	22	Activated Sludge -V.F.- Land Fill	43	20(1)
	8.5	T.F. (2.0 MGD is Sanitary Sewage)	65	80(1)
Meat Packing				
	0.53	Anaerobic Lagoon-Sludge Deposit in Lagoon, Effluent to City Aerobic Facilities	57	31(1)
	0.60	Anaerobic Contact Pretreatment, Effluent to City Sewer	122	7(1)
	0.85	Primary Clarifier-Balancing Tank-Anaerobic Pond-Oxidation Pond	130	9(1)
Chemical		Primary Treatment		
	0.1	Chlorination Followed by Neutralization with Lime, Clarification-Incineration	688	
	4.0	10 Settling Pond	69	
	0.8	pH Control-Settling-Land Fill for Solids	688	10(2)
	0.6	Settling	28	
	0.6	Neutralization-Settling-Equalization-As Removal-VF	11	

(1) BOD_5 (2) SS (3) COD

Industry	Flow Rate MGD	Type of Treatment	Daily Operating Cost (Exclusive of Amortizat) $/MG	$/1000 Pollut. *
Chemical	0.8	Grit Removal-Neutralization with Lime-Coag. with Alum-Settling-Sludge Dewatering-Sludge Lagoon	153	40(2)
	0.5	Neutralization-Settling-Land Fill	1540	
	1.89	Neutralization-Alum Coag.-pH Adjustment-Filtration through Diatomaceous Earth- Sludge by Ponding	208	
	0.05	Chrome Removal-pH Adjust.-Settling Pond	442	
	2.16	API -Lagooning (No Aeration)-Land Fill	95	76(1)
	0.90	Equalization-Neutralization-Lagooning	132	3(2)
	0.6	Equalization-Modified Extended Aeration-Oxidation Pond-Aerobic Digestion-Land Fill	230	734(1)
	0.325	Equalization-Modified Extended Aeration-Oxidation Pond-Aerobic Digestion- Land Fill	255	136(1)
	0.4	Extended Aeration-Digestion-Land Fill	276	26(1)
	0.1	Comminutor-Extended Aeration-Nutrient-Stabilization Pond	276	7(1)
	1.5	Extended Aeration-Activated Sludge Lagoons	221	14(1)
	2.0	Extended Aeration-Sludge by Anaerobic Lagoon	65	4(1)
	3.6	Nutrient-Aerated Lagoon	31	47(1)
	3.0	Stabilization-Aerated Lagoon-Digestion-Land Fill	35	6(1)
	0.2	Neutralization-Clarification-Aerated Lagoon-Land Fill	1160	477(1)
	4.32	Neutralization-Nutrient-Contact Stab.-Clarification	16	23(1)
	0.55	Contact Stabilization-Land Fill	211	106(1)
	0.35	pH Adjustment-Equalization-Settling-Mixing-Activated Sludge-Clarifier	1580	100(3)
	1.06	pH Adjustment-Equalization-T.F.-Lagoonings	780	49(1)
	1.40	Grit Removal-Equalization-Neutralization-Flotation-Activated Sludge-T.F. -Aerobic Digestion-Land Fill	334	28
	2.59	Lime Neutralization-Clarifier-T.F.-Act. Sludge-Sand Filter	378	245
	1.69	Facultative Pond-Land Fill-Burning of Solids	163	39
	0.036	Mixco Agitator with Sparging Ring	3830	
	0.019	Mixco Agitator with Sparging Ring	4360	
Poultry	0.1	Screening-Settling-T.F.-Clarifier	2050	3750

(1) BOD_5 (2) SS (3) COD

APPENDIX C-2

MUNICIPAL SEWAGE TREATMENT OPERATION COSTS

Flow Rate MGD	0.1	0.5	1.0	5.0	10.0
Primary Treatment $/MG	62	35	3.0	21	19
Activated Sludge Plants* $/MG	147	77	57	44	33
High Rate T. F. * $/MG	110	50	37	25	21
Standard Rate * $/MG	195	47	29	17	14

*including primary treatment